METALLURGIA

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Electric Heating Furnaces

Some Very Large Installations

(Specially Contributed.)

The application of electricity to industrial heating is expanding. Its advantages together with intensive metallurgical research and improvements in the design of furnaces are gradually increasing the size and capacity of installations.

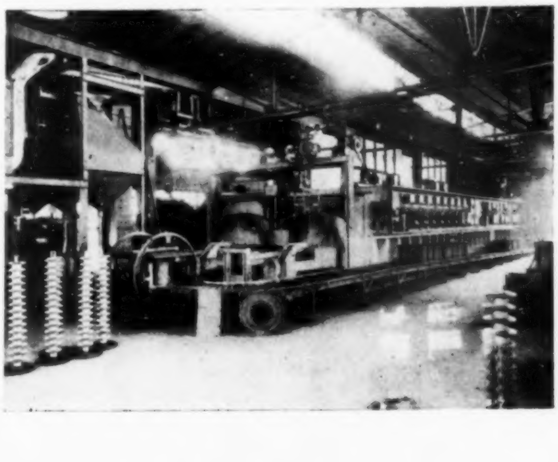
THE application of electric heat to industry is still in a relatively early stage, and although great progress has been made during recent years in its use for industrial purposes, there is every likelihood of greater strides being made in the near future. The rapidly expanding application of electricity to industrial heating operations is not due to a lower energy cost in comparison with fuel—often its energy cost is higher,—but is primarily due to the possibilities it offers for improving the quality and reducing the cost of heat-treated products, and to the provision of improved facilities for the operatives. Its use offers certain indirect advantages which influence manufacturing processes and tend to simplify and improve technique.

It will be appreciated that the selection of the right type of heating equipment is frequently a matter of compromise. Many factors must be considered, and the conditions existing in the plant are frequently a deciding factor. Manufacturing requirements are very diverse, and plant conditions exercise a powerful influence in determining the particular form of furnace best suited to the circumstances; this obviously affects the question of heat energy. Whether heated electrically or by fuel, each form of equipment has a particular field of usefulness in industrial heating, just as power plant developed by water, steam, oil, compressed air, or electricity has its particular uses. While there may be, and frequently is, great similarity in furnaces using fuel, the characteristics of electric furnaces are distinct. They may vary much in form and in detail, but all embody the fixed thermal value of the kilowatt hour, the conversion of energy without combustion, and the exact control of energy converted.

The initial cost of the heating medium is important, but should not be a primary consideration without reference to the production costs as a whole, as the indirect advantages offered by the use of electricity may compensate for any higher energy cost. The fact that there are no products of combustion to contaminate the work; both temperature and atmospheric control are readily obtained; heating can be localised to any part of a furnace; hydrogen or carbon monoxide gases can be maintained without muffles; dependence on the human element is reduced; and automatic operation is easily obtained, which facilitates night service—gives the electric furnace advantages which influence quality and also the overall cost of the products.

The increasing use of electricity in the industrial heating field is indicated by the upward trend in kilowatt hours consumed during the last few years. Much of this progress is undoubtedly due to intensive metallurgical research, to the many improvements embodied in the designs of heating furnaces, and to the gradually increasing size of different electric installations of this type. Some indication of the progress made can be gauged from the following illustrations and descriptions of designs by the Hevi Duty Electric Co., Milwaukee, Wisconsin, U.S.A., a firm that has played an important part in applying electric energy to industrial heating.

Fig. 1. Electric Regenerative Counterflow Furnace, used for carburising gears and shafts. It is fully automatic.



Large Regenerative Counterflow Furnace.

The furnace shown in Fig. 1 is a large regenerative counterflow furnace, approximately 48 ft. long, with a rated capacity for carburising gears and shafts, of 50,000 lb. of gross load per 24 hours, including containers and compound. The furnace has a double chamber, each chamber containing two compartments running lengthwise, with two mechanically operated doors at either end of the furnace, each door exposing the two compartments. This arrangement of paired compartments makes two distinct furnaces, and hereafter will be spoken of as a unit.

In Fig. 1 the inverted pots with the charge and compound are shown loaded on trays, travelling down a gravity roller conveyer, which completely surrounds the furnace. The pots in alternate rows move in different directions in the furnace chamber by the force of a ram at each end. Once every hour the doors open automatically, and the ram pushes a waiting tray into the furnace, at the same time, by a successive contact of trays, a tray emerges at the other end. These loaded trays travel on three rows of alloy disc rollers, which reduce the frictional load to a minimum. The rolls are of the rail and trunnion type, mounted on top of continuous fire-brick piers.

Measuring from either end of the furnace, the first 12 ft. include the cooling or preheating zone, depending upon whether the charges are entering or leaving the furnace. There is no dividing wall here, one arch being thrown across both rows, thus enabling an advantage of an interchange of heat between the hot and cold work through radiation and convection. Heating elements of the nickel-chromium round-rod return-bend type are mounted on the side wall of the preheating chamber to compensate for the heat of the hot charge leaving the furnace soaking chamber. At the entering end the next 6 ft. of space is the heating zone, which contains heating elements on all four sides—that is, the side walls, the roof, and in the hearth. Here the charges are rapidly brought up to a carburising temperature of approximately 900° C. Immediately following is the soaking zone, 16 ft. long. In this zone heating elements are provided only in the floor. There is a dividing wall between the compartments containing the heating and soaking zones. At the discharging end of the furnace, the pots are run on to a dumping grate, which allows the compound to fall in a hopper leading to a conveyor, which elevates it to a screen and storage bin for later re-use.

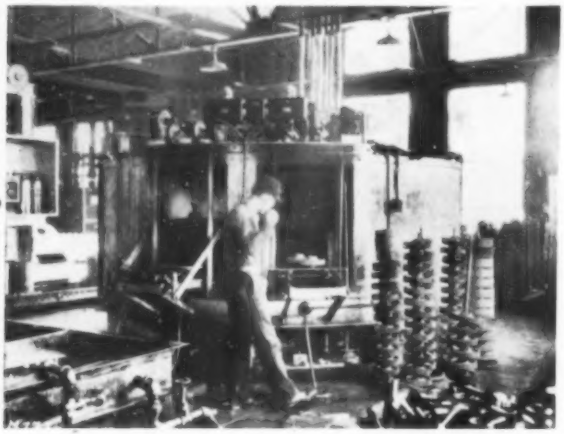


Fig. 2. One of the two "Hevi Duty" Electric Rotary Hearth Furnaces, used for case and core refinement of carburised parts.

The furnace rating is 360 kw., with 230 volts, 3-phase. Each unit has four zones of control, eight in all. The temperature is maintained by eight recording control pyrometers mounted on the side of the furnace shown in Fig. 1. Four of the thermocouples are placed in the heating zone of each compartment and four in the soaking zones, toward the cooling end. This allows separate temperatures to be maintained in each row.

Four electric clocks time the automatic opening and closing of the furnace doors at each end, and actuate the pusher or ram mechanism. The normal cycle of carburising to the depth of case required requires 26 hours, with a 10-hour cooling period after the pots leave the furnace. This furnace can also be used for annealing.

Rotary Hearth Furnaces.

At the same manufacturing plant where the above carburising furnace is installed, are two large rotary hearth furnaces with 150-kw. rating each. Fig. 2 shows one of the rotary hearth furnaces; the other one is identical. In one furnace small carburised gears and shafts weighing up to 40 lb., are placed for core refinement, then they are quenched in oil, reheated in the second furnace to the proper temperature for case refinement, and quenched in water.

Each furnace has a door for loading and one for unloading. Both are elevated and closed by means of a separate motor-driven unit actuated by a control button placed on the floor and operated by the foot. By this means the operator can remove the charges and drop them into a quench tank without taking more than one or two steps.

There are three zones of heat control in each furnace, with a thermocouple lead in each. The temperature in each zone is maintained by an independent controlling pyrometer. The round-rod return-bend-type heating elements are mounted under the hearth and on the side walls. The charge loaded on to the moving hearth, through the charging opening, passes through the three heating zones as the hearth rotates in the furnace, after which it is unloaded through the discharge opening. From 1,200 lb. to 1,400 lb. of gears can be heated per hour. The cycle of the hearth is approximately 1 hour and 20 mins., but may be varied when different sizes of gears are heated. The maximum operating temperature is 1,000° C.

Car-Type Regenerative Electric Furnace.

Fig. 3 shows two regenerative counterflow furnaces of the car type. These furnaces are used for annealing magnetic materials used in telephone apparatus. The parts to be annealed are placed in annealing pots, which are shown loaded on the cars, Fig. 3, waiting to be pushed into the furnace chamber. The cars not only transport the pots through the furnace, but also provide heat to them.

Two tracks pass through the furnace from end to end. The cars on one track move in an opposite direction to the cars on the second track. This movement makes recuperation of heat possible. The interior of the furnace is divided into three chambers. First, a preheating and cooling chamber with no dividing wall, thus enabling the discharging pots to radiate their heat to the entering cold pots; then the heating chambers, with a dividing wall which has the nickel-chromium round-rod return-bend-type heating elements on both sides, the roof, and in the car top when in position: third, the cooling and preheating chamber. The doors at each end of the chamber are raised and lowered pneumatically by means of an air-control valve.

The cold charge brought into the preheating chamber remains there 6 hours, and reaches approximately 370° C. by means of absorbing the heat from the heated charge in the cooling section. Then the car is moved in the heating chamber and brought up to 900° C. At the end of a 6-hour period the heated charge is moved into the cooling chamber for 6 additional hours; here it discharges part of its heat to the preheating section, and is at approximately 370° C., when it leaves the furnace. The car, with charge, is then moved to a cooling hood, which is pulled down over the stack of pots to the car top. A motor-driven fan exhausts the heated air rising from the pots to the exterior of building.

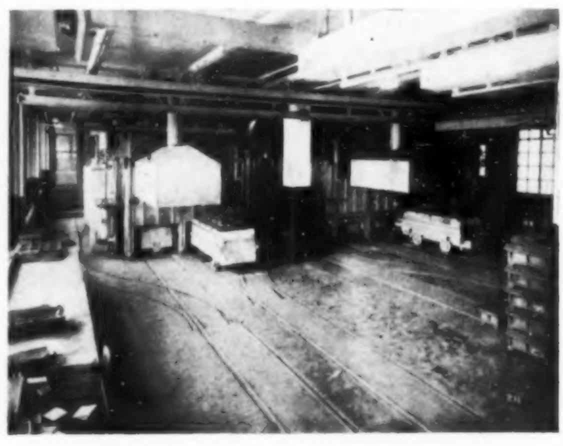


Fig. 3. Two Electric Car Type Regenerative Counterflow Furnaces, used for annealing magnetic parts for telephone apparatus.

The time cycle for the complete annealing operation requires 23 hours. Six hours preheating, 6 hours heating, and 11 hours cooling.

The furnaces have a rating of 360 kw., with four zones of control, two zones in each furnace. The temperatures are accurately maintained by means of four recording controlling pyrometers. A net load of about 12,000 lb. of small magnetic parts, and 10,000 lb. of small parts for subsequent machining operations, are annealed daily in these furnaces.

Car-Bottom Furnaces.

Fig. 4 shows a large car-bottom furnace and cooling chamber located in a steel-casting manufacturing plant, being used for annealing castings at 900° C. A furnace car is shown outside the cooling chamber, waiting to be loaded with a charge. The furnace has a rating of 335 kw., 240 volts, 3-phase. The furnace cars have a loading space 5 ft. wide by 10 ft. long, and the height to the spring line of the arch is 4 ft. 6 in. from the top of the car. Nickel-chromium heating elements are located in the car top, which assists greatly in bringing the 8 or 9 ton charge, which is placed on the car, up to heat in the minimum length of time. Heating elements are also installed on the side walls, roof, rear wall, and in the furnace door. When hearth resistors are required, a third rail and collecting shoe on the car or a flexible cable arrangement supplies the current to that part of the heating circuit.

Temperature is controlled by placing a thermocouple in the car top, one in the roof, in the mid-side wall towards the front, and one in the mid-side wall toward the rear. This arrangement provides a means of determining when the charge has come up to heat, from which point the soaking period is timed.

The furnace cars are mounted on wheels, which move in and out of the furnace on rails by means of a motor drive. There are two transfer cars on which the furnace cars with their loads are run. This facilitates a transverse movement, enabling the heated charge to be moved into the cooling chamber in a minimum length of time. The new charge, which is to be heated, can then be moved into the heating chamber.

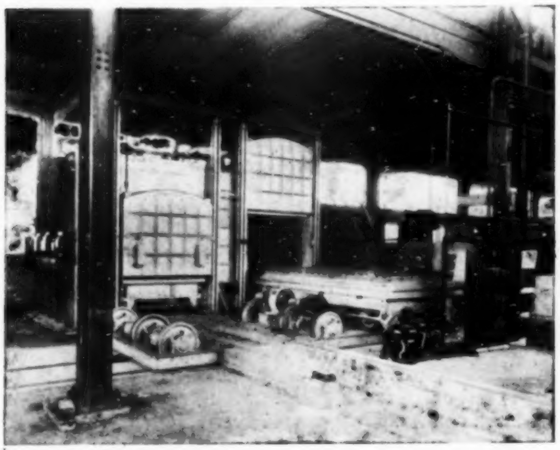


Fig. 4. Electric Car Bottom Type Furnaces, with an empty car outside the cooling chamber. A car with charge is shown in the heating chamber.

Carburising with Carbonal.

Recent developments have brought about an improved type of carburising and nitriding furnace. The similarity of the two operations makes this design possible. Fig. 5 shows four of these furnaces using carbonal, a Hevi-Duty patented liquid carburising agent, for carburising rotors, valves, valve seats, and caps. Each furnace is rated at 72 kw., 230 volts, 3-phase, having two zones of control. The carburising temperature is maintained by two thermo-couple leads in the furnace chamber connected with a control pyrometer and a recording control pyrometer.

The charge is loaded in baskets, Fig. 5. Approximately 1,000 lb. can be loaded in each furnace per charge, with no attempt to keep the parts from contacting with each other. However, they should be placed to allow the circulation of the carburising medium to take place throughout the charge. In this way maximum of uniformity in penetration and structure is obtained. The loaded basket sits in an alloy retort inside the furnace chamber. Over this a special cover is set and firmly bolted, which seals the working chamber. A motor-operated centrifugal fan, incorporated in the cover, circulates the carburising gases throughout the charge.

Fig. 5. Four Electric Vertical Carburising Furnaces, using "Carbonal," a liquid carburising agent.

The furnace and charge are brought up to heat with the fan running, which gives a rapid and uniform rise to carburising temperatures of from 930° C. to 940° C., depending upon the type of steel used and kind of case structure wanted. The carbonal is then dripped into the hot retort through an inlet in the furnace cover. Carbonal, high in hydrocarbons, entering the furnace, is forced outward against the hot retort by the centrifugal action of the circulating fan, where it is immediately cracked up into hydrocarbon gases. The resultant gases are circulated through the charge and the steel is thus exposed to a very active carburising agent. Forced circulation assures fresh uniform gas being brought to the work continuously.

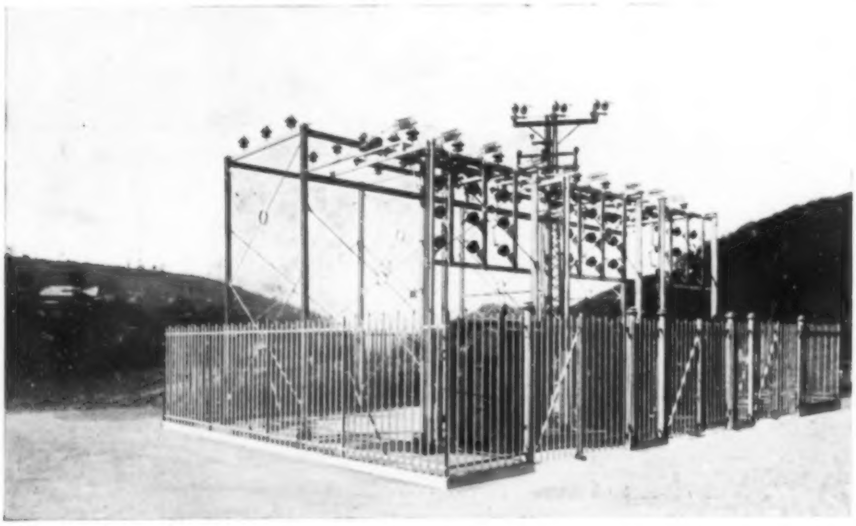
Carburising proceeds very rapidly. A penetration of from 12 to 15 thousandths of an inch at 930° C. takes place per hour. After the carburising cycle is complete the retort is lifted out by an overhead crane and removed to a separate cooling pit or may be cooled on the floor, while a second loaded retort is placed in the furnace. In some instances the carburised work is quenched from or a little under carburising temperatures. This is accomplished by removing the cover and handling the charge direct to the quench by means of the basket which holds the charge.

Besides the carburising and nitriding operation of these units, they can be used for normalising or annealing with controlled atmospheres. Also, it can be used in the non-ferrous field for bright annealing through the use of either a liquid protecting medium or special gases.

It should be noted that many of the features described in the foregoing article are the subject matter of patents in European countries, where the manufacture and sales of Hevi-Duty electric furnaces are controlled by Wild-Barfield Electric Furnaces, Ltd., and G.W.B. Electric Furnaces, Ltd.

Electrical Equipment at Lydney and Crump Meadow Colliery.

A considerable amount of electrical apparatus has been installed in connection with the development of the Arthur and Edward Colliery of the Lydney and Crump Meadow Collieries Co., Ltd., and we are indebted to the proprietors and manager of the Collieries for the following information respecting this installation and for permission to reproduce, in the accompanying illustration, a photograph of the sub-station. This installation comprises a 33,000-volt transformer outdoor sub-station equipment, truck cubicle switchboard on the surface, and pedestal oil-immersed switchboards, haulage-gear motors, and motor-control gear, motor-driven turbine pumps, etc., below ground. The contract for this plant and apparatus was placed with the General Electric Co., Ltd., Magnet House, Kingsway, London, the gear being manufactured at the Company's Witton Works, Birmingham.



A view of the 33,000-volt Outdoor Substation.

The incoming power is taken from the 33,000-volt, 50-cycle overhead lines of the West Gloucestershire Power Co., and transformed down to 3,300 volts. The equipment on the high-tension side of each transformer consists of a triple-pole horn break-switch, with choke coils, and a triple-pole isolating link with fuses. The structure which carries this switchgear is built up of H stanchions, with channel and angle members.

The transformers are each of 500 kw. output, 31,500/3,300 volts, 50 cycles, with primary tappings at plus and minus $2\frac{1}{2}\%$ and 5%. They are of the G.E.C. standard three-phase oil-immersed self-cooled core type, and of outdoor pattern enclosed in a sheet-steel tank fitted with radiating and circulating tubes. The connections are arranged star-star.

Standard outdoor shed-type porcelain terminals are fitted on the high-voltage side, and on the secondary side straight-through porcelain bushes are fitted, these being protected by cowls. The tank is complete with oil drain, oil-level gauge, thermometer pocket, earthing device, and rollers. The H.V. winding is wound with cross-over coils, while the secondary side is of the spiral type. Both windings are vacuum-impregnated and treated for shrinkage before assembly. Pure pressboard, suitably treated, is used for the major insulation.

The power from the low-tension side of the transformers is controlled by the 3,300-volt G.E.C. truck cubicle switchboard, situated in the switchgear house closely adjoining the sub-station. Apart from the three cubicles controlling the low-tension side of the transformers, there are two metering cubicles and two controlling outgoing feeders. The pedestal oil-immersed pillars on either side of the truck switchboard control lighting circuits.

The pit-bottom switchboard is of the pedestal oil-immersed draw-out type, comprising 6 units. Two of these control the incoming shaft feeders, two control the circuits supplying power for haulages, the fifth is for lighting, while the sixth controls the feeder to the pumping station. Metering equipment is attached to the unit controlling lighting. The G.E.C. oil-immersed pedestal type of board is particularly suitable for colliery service, being of very robust construction, and providing maximum safety in operation, due to the draw-out feature.

The electrically driven equipment below ground includes two main haulages, each driven by 130 h.p., 3,300 three-phase Witton induction motors. The control gear for each motor consists of three items of apparatus, a main oil-immersed draw-out pillar, as described above, an oil-immersed stator reversing contactor, and a horizontal oil-immersed drum-type controller. The oil-immersed stator reversing contactor is provided with potential transformer and high-tension fuses, while an electrical interlock prevents the tank being lowered while the switch is closed. A feature of this contactor unit is that all three phases are broken when reversing, thus making the motor dead.

The horizontal oil-immersed drum-type controller presents many special features of design. Thus, the drum section is fixed to end brackets on the lid of the controller, so that it is very accessible when the lid is open. Further, the lid can only be opened or closed when the operating handle is in the "off" position. Also, when the controller is in the "off" position the motor is completely isolated from the line, all three phases being broken by the controller.

The Manufacture of Bronze Propellers.

In a lecture on the manufacture of bronze propellers delivered before the Lancashire Branch of the Institute of British Foundrymen at Manchester on May 2, Mr. Wesley Lambert, a past President of the Institute, referred to what is believed to be the first official account of the application of screw propulsion to a marine vessel. The evidence on the document, which was projected from a lantern slide on to a screen, was dated 1802. The screw was used as an auxiliary in propelling the vessel, and the statement indicated that in calm weather the screw had been used to such an advantage that it propelled the vessel at a speed of $1\frac{1}{2}$ knots per hour. Much progress has been effected since that time, and Mr. Lambert showed some excellent illustrations of propellers for many modern vessels, including the "Europa."

Some time ago Mr. Lambert discussed the metallurgical features of manganese bronzes for propellers before a meeting of the Manchester Metallurgical Society, at which members of the Institute of Foundrymen were invited. At this meeting the discussion concerned the process of manufacture in the foundry, and members of the Metallurgical Society were invited to give them the opportunity of grasping the fundamentals in the manufacture of the finished castings. With the aid of lantern slides Mr. Lambert described the various processes from the drawing to the finished casting.

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Promoting Trade in the Far East.

THE future possibilities of increased trade in the Far East have been reviewed by the British Economic Mission, and the conclusions are both informative and instructive. The Mission's views embrace textiles as well as trade iron and steel and engineering. The Japanese are a very progressive race, and during the last twenty years have made rapid developments industrially. Particularly is this true of the iron and steel industries, and, engineering. The requirements of Japan have grown and in respect of iron ore necessitate considerable importation in order to maintain her normal production of pig iron, which is at present 1,400,000 tons. This production does not fulfil her needs, as about 650,000 tons is imported in addition. The iron and steel works are apparently producing under difficulties, and are feeling the effects of the import of Indian pig iron; in consequence they are pressing for further assistance by way of increased import duties, bounties, and the application of anti-dumping measures.

The present productive capacity of steel is nearly two million tons a year, but, to meet requirements, she has to import nearly a million tons. Schemes are under consideration, however, for rationalising the industry with the object of increasing production, and it is asserted that over-production is noticeable in many lines already. Obviously, under such conditions steel importers will find it difficult to secure orders excepting at very low prices, and then only in lines in which Japanese production is insufficient. A revival of trade will undoubtedly give opportunities for increased import of both iron and steel products, because Japan is not yet sufficiently organised in the production of these goods to meet extra demands. The recommendation is made that manufacturers desiring to take advantage of such openings should have resident experts in Japan.

In the production of machinery the Japanese Government give energetic assistance, which enables works to compete keenly with imported products. As far as work for Government services is concerned, this will doubtless be carried out by Japanese firms, but the increasing development of the country, the demand for improved public utilities, and the increased demand for the amenities associated with an improved standard of living, will necessitate a greater proportion of imported machinery than is required at present. Close investigation by manufacturers of the possibilities of co-operation with Japanese industry in various ways will assist very considerably in making trading possible.

Industrial conditions in China are not as advanced as in Japan, but reconstruction and modernisation are proceeding fairly rapidly, and will absorb increasingly large quantities of metals and machinery. The Chinese Government appreciate the possibilities, and have appointed Ministries, Boards, and Commissions, which are giving close attention to the formidable problems connected with speeding-up and facilitating development. China will undoubtedly develop an iron and steel industry of her own, with a view to meeting her own requirements, but her industrial future has great possibilities that are not likely to be fully met by her own resources, and the nations that go farthest in helping China in her task of reconstruction will have ample opportunities for promoting trade facilities. Competition for orders is undoubtedly keen, but in machinery and constructional work the market is by no means a rock-bottom one; frequently a good article is preferred if its superiority is convincing.

Improved transport facilities would enable China to develop exports, besides opening up the untapped markets in the interior; the development of China's export trade, and the establishment of manufacturing industries, would increase China's purchasing power. Foreign manufacturers and exporters thus have two opportunities—that of selling railway material, etc., and machinery to develop the country, and that of selling other goods to meet the increasing demand which that development would foster.

Credit is a more important factor than price, particularly in regard to large contracts and large plant. The Mission emphasises the fact that risks will have to be taken if orders are to be obtained, and as merchants and manufacturers cannot take a sufficient place in financing their developments by themselves, intelligent and sympathetic cooperation of financial interest is essential. This method will assist in counteracting the financial penetration by other countries, which, by granting credits and purchasing concessions are not only gaining a strong position, but are undermining the goodwill of old-established British houses.

It is clear that the Chinese Government, supported by the nation, are developing a policy of industrialisation, and in this development British capital should play its part without restraint. Apparently, contracts have been lost to British manufacturers because credit has not been forthcoming, and while the problem of giving long-term credits is a difficult one, it is to be deplored that orders should be lost through lack of suitable financial facilities.

Similar complaints have been made regarding the inadequacy of British finance in Japan, and in order that the British export trade should have at least as favourable consideration as the export trade of competitor countries, the Mission recommends that the Department of Overseas Trade should call a conference at an early date at which British bankers, industrialists, exporters, and merchant houses interested in the Far Eastern markets should be represented, for the purpose of inquiring into complaints made, and deciding what action should be taken. The continued decline in the value of silver has materially reduced the purchasing power of China, and compels her to raise further revenue by increasing import duties, and this, if continued, will give an impetus to the growth of industries in the country, thus reducing the demand for foreign goods. The stabilisation in the value of silver would have considerable influence in restoring to China her full purchasing power, but this can only be done by international agreement, and Great Britain could well take a leading part to secure such an agreement.

In order to promote British trade in the Far East, the Mission recommends that a British service of specialists or experts should be established in those countries which are undeveloped or in which British trade shows the greatest decline. This service should have complete freedom of action in its own sphere, and should report direct to the Department of Overseas Trade. Its personnel should be recruited from first-class men with the requisite initiative and resourcefulness to conduct business. Those firms that cater specially for export trade should carefully consider, without delay, whether a method of grouping

for export purposes can be applied with profit to themselves, as the importance and value of investigation of a market when followed by combined action for export have strongly impressed the Mission throughout the inquiries, and firms which individually cannot afford the expense involved will, by adopting this method, benefit by a large scale organisation for investigation, intelligence, and increased sales.

The Corrosion of Iron and Steel.

IT would be exceedingly difficult to estimate the loss sustained year by year as a result of the corrosion of metals; certainly it would represent a very impressive sum. In view of this continual loss and the progress of metallurgy, it is not surprising that attention should be increasingly directed to the problem, and much time has been devoted to the investigation of its causes in order to seek remedies. But the elucidation of the factors that determine the rate and character of corrosion in any particular case is apparently becoming more complex with increased knowledge of the subject. So many factors have been shown to exert important influences on the metal that a complete investigation is necessary to enable all the known causes to be studied together rather than separately. The task of studying corrosion problems in regard to iron and steel has been undertaken by a Joint Committee of the Iron and Steel Institute and the National Federation of Iron and Steel Manufacturers, and the first report of this Committee was presented at the recent annual meeting of the Iron and Steel Institute.

Composed primarily of experts in the various branches of industry particularly interested in corrosion problems, this Committee was formed about three years ago to investigate: (1) The corrosion of ordinary steels, as affected by variations in composition, by methods of manufacture, and by conditions of use; (2) the corrosion problems arising in steam practice, including high temperatures, as regards superheaters, etc.; (3) critical consideration of rust-resisting and allied steels; (4) any other matters relevant. Its constitution is such as to ensure that all tests are made on materials of known origin and composition, manufactured for the purpose under perfectly defined conditions, which have been thoroughly examined, both by physical and chemical methods, prior to acceptance. The complete history of all materials tested will be known from the time the charge is put into the furnace until the conclusion of the tests.

The main object of this Committee is to ascertain, both by practical exposure tests and by the investigation of cases in which the iron or steel has been found to corrode rapidly, how much corrosion can be reduced to a minimum, either by improving the material itself or by adopting methods of protection. In this way it is hoped to effect material improvements in the corrosion resistance of iron and steel, which will permit of a much more extensive use of these materials in permanent structural work with satisfaction. Although much research work is already in hand on corrosive problems generally, it is the Committee's intention to explore the entire field of the corrosion of all types of ferrous products. The researches will consist primarily of a series of field tests to be conducted by approved scientific methods under well-defined service conditions over prolonged periods.

The report refers mainly to methods to be adopted in various investigations and experiments, as subsequent reports giving accounts of the experiments undertaken by the Committee, with the results achieved, are to be published. The present report deals with the correlation of knowledge and data concerning corrosion. It is subdivided into sections, the second of which contains a critical examination of the replies to a questionnaire which asked producers and consumers of iron and steel to give their experience on the corrosion of iron and steel products under specially defined service conditions, effect of different service conditions, effect of small differences in compositions of the steel, conditions of rolling, the effect of a copper addition, and several other questions. Another section gives full experimental details of field tests, the work in progress or already arranged, including field tests on the corrosion of ordinary structural mild steel with or without the addition of small amounts of copper. Arrangements have been made for a number of independent laboratory investigations and these are described in another section. It is hoped that the investigations will lead to correlation between laboratory experiments and the results of field tests, so that it will be possible to predict results either of a laboratory or a field test with greater certainty.

Conference of British Foundrymen.

THE twenty-eighth annual conference of the Institute of British Foundrymen is to be held at Birmingham on June 9—12, and a very full programme of arrangements has been prepared. A feature of this conference is a visit to Coventry, the home city of the President-Elect, where will be found many unique points of interest, both industrial and historical. Exchange papers from similar organisations in other countries, which are a feature of the Foundrymen's conferences, will be given on behalf of the American Association by G. W. Spring, Chicago, U.S.A., the Association Technique de Fonderie de Belgique, by Professor H. Thyssen, University of Liège; and the Association Technique de Fonderie à Paris, by M. Arzens. In addition to the exchange papers, six other subjects will be discussed which will cover many phases of absorbing interest in the foundry industry. A new feature has been introduced into the discussions, which formerly have been confined to technical subjects, by a consideration of the relationship between the engineering and foundry trades and the subject of marketing castings.

Members are given opportunities to visit many widely divergent foundry activities in the Midlands, and ample facilities are being arranged to enable members and their ladies to visit some of the rural and historic beauty spots of the district.

Forthcoming Meetings

ROYAL SOCIETY OF ARTS.

June 4. A paper to be read by Mr. J. F. J. Malone, describing a new form of prime mover and its uses for locomotive, marine, and other engines. A full demonstration will be given of the principles of this new type of engine, which derives its motive power from the expansion and contraction of fluids. The meeting will be held at John Street, Adelphi, W.C. 2, at 6 p.m., and will be presided over by Mr. Llewelyn B. Atkinson, M.I.E.E., Assoc.M.Inst.C.E., a vice-president of the Royal Society of Arts.

INSTITUTE OF BRITISH FOUNDRYMEN.

June 9–12. Twenty-eighth Annual Conference at the Grand Hotel, Birmingham.

June 9. General Council Meeting.

June 10. Conference. Papers: "The Effect of Elevated Temperatures on Grey Iron Castings," by G. W. Spring; "Factors in the Conductivity of Irons," by Professor H. Thyssen; "The Laboratory and the Foundry," by M. Arzens; "The Merchandising of Castings," by Eric N. Simons; "Sands and Sand Testing," by J. G. A. Skerl, D.Sc.; "Silicon as an Alloying Element," by John Arnott, A.I.C.; "High Duty Light Alloys," by W. C. Devereux. Annual Banquet, 7 p.m.

June 11. Conference continued at St. Mary's Hall, Coventry. Papers: "The Relationship between the Engineering and the Foundry Trades," by L. H. Pomeroy, M.I.Mech.E., M.I.A.E.; "Recent Developments in Cast Iron in Great Britain," by J. G. Pearce, M.Sc., M.I.E.E.

INSTITUTION OF WELDING ENGINEERS.

May 28. Eighth Annual General Meeting, followed by an Informal Lunch, at 1-15 p.m. at the Belgravia Hotel, Victoria, S.W. 1.

Correspondence.

"Bliss" Rolling Mills.

The Editor, Metallurgia.

Dear Sir,—I have been very interested to read the article published on page 191 of your March issue, descriptive of rolling mills built to the designs of the E. W. Bliss Co., of Salem, Ohio, especially those of the backed-up roll type.

I would, however, point out one or two inaccuracies in the statements. Whilst the Four-High and "Cluster" designs are being increasingly employed for cold rolling wide strip and sheets, it is scarcely correct to state that they are "gradually replacing" the Two-High Mill.

The Backed-up roll Mill has undoubtedly great advantages for strip metal exceeding, say, 15 in. wide, especially in light gauges, but for lesser widths the modern development of the high-speed Two-High Mill is equal if not superior in efficiency and productive capacity, and is at the same time simpler and less costly. It is, also, very doubtful whether the power consumption *per ton* of metal rolled with any given reduction is appreciably less with the Four-High or "Cluster" Mill than with the latest type of high-speed "Duo" Mill.

With regard to the maximum width of strip which can be satisfactorily rolled in a Two-High Mill, I have records of actual practice showing that for thicknesses 0·035—0·015, a width equal to 70% *of roll diameter* can be efficiently rolled, not only 50% as stated, and between 0·015 and 0·005, and also widths up to 75% of roll diameter are regularly rolled with the heaviest possible percentage reductions at exceptionally high speeds.

I note that rolling speeds for Two-High Mills are stated as being from 60 to 120 ft. per min. for heavy draughts. This is, of course, old practice, and mills installed during the last three or four years in this country are working at much higher speeds :—

Cold rolling steel strip, 150 to 250 f.p.m.

Cold rolling brass and copper strip, 150 to 350 f.p.m.

I assume, however, that the data given is based on American practice. If so, it would appear that in some respects modern British practice is superior.

The statement that the arc of contact between rolls and metal is equal to radius of roll × total reduction is not correct, and this should be :—

Arc of contact $= \sqrt{\text{Roll radius} \times \text{reduction}}$ (approx.).

This is, however, probably a printer's error, as in the example given the roll pressures are correctly calculated by the formula $\sqrt{R.d.}$ —Yours faithfully,

C. E. Davies, Director,
W. H. A. Robertson & Co., Ltd.

"Bliss" Rolling Mills.

The Editor, Metallurgia.

Dear Sir,—We note with interest the criticisms forwarded by Mr. Davies in his letter to you of April 15 on the above subject.

At the outset, we are pleased to note that your contributor is in full agreement with us respecting the advantages of the Four-High and "Cluster" design mills for dealing with wide sheet and strips, especially on light gauges. We cannot, however, agree that for widths under 15 in. the Two-High Mill is a more favourable proposition, since we have data showing that a number of firms in England are to-day installing Backed-up type Mills to replace the Two-High Mills; in fact, instead of "gradually replacing" the Two-High Mill, one is inclined to believe from the present indications of the market that this "gradual" will very soon have to be altered into "rapid."

For the purpose of rolling 6 in. and 7 in. wide strip when the total reduction required is 80% of very hard steel, the Brinell hardness before the last pass is in the region of 400, and to carry out such duties on a Two-High Mill would be a heavy responsibility for the designer in order to ensure smooth working, lower power consumption, avoidance of roll breakages and efficient output.

We have, amongst other installations, supplied a Cluster Mill for rolling molybdenum strip 4 in. wide, and your correspondent will no doubt be interested to learn that this mill is undertaking the duties of the Two-High Mill, which it replaced, using one-sixteenth of the motive power, and rolling down to requisite gauge, the number of passes being 75% less than those taken formerly. The final sheet is more highly finished and also of better quality than before, after being subjected to most exacting microscopic and other tests. There is also on record the example given in the article.

In America it is common practice to roll 2 in. and 3 in. wide strip on Four-High Mills with most satisfactory results, and these results could not possibly be obtained on a Two-High Mill dealing with anything like the same output. No doubt it is possible to roll a maximum width of strip on a Two-High Mill equal to 75% or even 100% diameter of the roll, but obviously the nature and class of material to be dealt with will be the determining factor, and due consideration will have to be given to the number of passes, output, and the final quality at the requisite gauge.

In the case of the Backed-up Mills the maximum width of strip which can be satisfactorily rolled for thicknesses 0·035 in. to 0·015 in. is a width equal to three to four times the diameter of the working roll, and this can be obtained with heavy reductions, a considerably smaller number of passes being involved.

We agree with your correspondent in his statement that the cold rolling of strip to-day is being effected at increased speed, but there are still a number of firms that adhere to the old practice of 60 to 120 ft. per minute, which bears out our statement in regard to the Two-High Mill fitted with brass or babbitt-lined bearings on heavy reductions.

On the Backed-up Mill speeds vary from 400 to 800 ft. per minute, and even 1,000 ft. per minute has been obtained on light draughts; in fact, there would appear to be no limit to the speed attainable on the Backed-up Mills, this factor depending entirely on the roller bearings.

There are firms in this country who have modernised and are at present bringing up to date their rolling Mill plants, but from observations and information gathered in America the writer does not think Mr. Davies is justified in stating that the English practice is superior to the American. One must take into account the vast internal trade in the States, and the large output attained by the most important sheet and strip manufacturers, and it is only by adopting the Backed-up type of Mills, which have been installed in America during the past ten to twelve years, that such a huge output can be attained on an economic basis. It is evident, therefore, that British manufacturers must ultimately modernise their plant on similar lines in order to compete favourably with foreign manufacturers who, by installing the latest design of Backed-up Mill, are placed in a better competitive position than we are.

In the tinplate trade modern requirements necessitate the production of sheet strip of even gauge, deep stamping quality, and surface, and these results can only be obtained by the installation of the Four-High and Cluster type Mills with a full cold rolling.

In conclusion, we would point out that these last-mentioned mills possess the following advantages :—(*a*) Economical working; (*b*) increased output; (*c*) saving of power; (*d*) production of high finish and better quality sheets; (*e*) low fatigue of rolls; (*f*) roller bearings giving advantages in speeds of rolling; and (*g*) saving of annealings.

We acknowledge, with thanks, Mr. Davies' correction respecting the formula given regarding arc of contact, which mistake, as he states, is due to a typographical error.—Yours faithfully,

For and on behalf of
Fraser & Chalmers Engineering Works,
D. M. Ross.

Hardening Metals by Rotating Magnetic Fields

By E. G. Herbert, B.Sc., M.I.Mech.E.

This newly developed magnetic phenomena is applicable to the hardening of tools of any type or design. Treatment occupies not more than two minutes at temperatures not exceeding 200° C.

THE effect of the rotating magnetic field on hardness was first observed in hard steel which had been superhardened by the Cloudburst[1] process of steel-ball bombardment, and the author originally[2] associated the increase of hardness so obtained with that which is known to occur in work-hardened metals when they are annealed at low temperatures (generally between 250° and 300° C. in ferrous metals). Later research showed that the effect produced in steel by the magnetic treatment is not a simple hardening, as was at first supposed, but that it gives rise to a sequence of hardness changes of a complicated and apparently of a periodic character, generally extending over many hours subsequent to the treatment. It was also found that the effect of the rotating field is not confined to superhardened or work-hardened steels, but that it can be produced in steels which have only been hardened by normal heat-treatment, in annealed steels, and in non-ferrous metals.

The subject was dealt with in a paper[3] presented to the Royal Society, and has since been carried further by investigations directed especially towards ascertaining the effect of varying the temperature at which the magnetic treatment is applied.

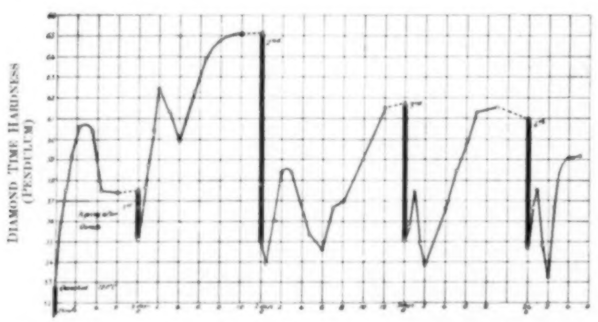


Fig. 1—Steel (0.76 C., 0.59 Mn., 0.15 Si.) quenched from 780° C; aged. 1½ turn in magnetic field, cold, repeated four times.

In Figs. 1, 2, and 3 are shown the hardness changes occurring in steel containing carbon 0·76, manganese 0·59, silicon 0·15, as a result of repeated magnetic treatment applied at different temperatures. In each case a specimen of the steel was first quenched in water from 780° C., and its hardness was tested immediately after quenching, and thereafter at half-hourly intervals. Every hardness number given in the present work is the average of from five to ten individual test results, each test being made by timing with the stop-watch five consecutive swings of the pendulum hardness tester. The hardness of the quenched steel rose to a maximum in 3 to 4 hours, and then fell somewhat. Virtual stability having been attained, the magnetic treatment was applied by placing the specimen across the poles of an electromagnet and rotating it once, the operation occupying about 2 minutes, and being conducted at room temperature (Fig. 1) at 100° C. (Fig. 2) and 200° C. (Fig. 3). The two latter treatments were given by rotating the specimens at the bottom of a bath affixed to the magnet and containing boiling water and oil at 200° C., respectively. The operation will be understood on reference to Fig. 17 which shows the electro-magnet with the bath and specimen in position. Hardness measurements were made immediately after the magnetic treatment, or as soon as the specimen had become cold, and thereafter at short intervals until the hardness became stable. The specimen was allowed to stand for an interval, as indicated in the diagrams, and the magnetic treatment was repeated.

The immediate effect of this treatment was in every case a fall in hardness, which was followed by a sequence of changes, these being generally reproduced after each successive treatment.

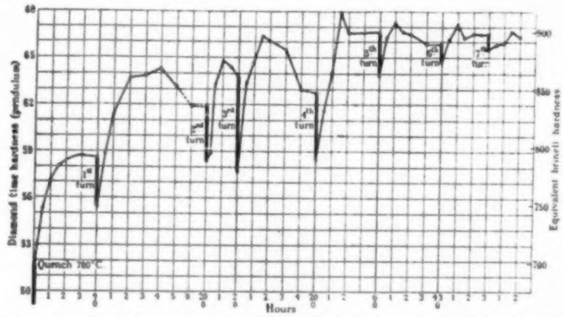


Fig. 2.—Steel (C. 0.76, Mn. 0.59, Si. 0.15); quenched 780° C., aged. One turn in magnetic field at 100° C., repeated seven times.

The characteristic sequences were :—

At room temperature	FALL, rise, fall rise.
At 100° C.	FALL, rise, fall.
At 200° C.	FALL, fall, rise, fall.

Similar experiments made with three safety-razor blades are illustrated in Figs. 4, 5, and 6, the magnetic treatment having been given at room temperature, at 100°, and 150° C., respectively.

Attention is drawn to the series of changes resulting from the first treatment at room temperature, Fig. 4, as these are believed to furnish a clue to the nature of the phenomena under investigation. There was a sequence of no fewer than six alternate increases and decreases of hardness, occupying gradually lengthening periods of time. Five changes were reproduced after the second treatment.

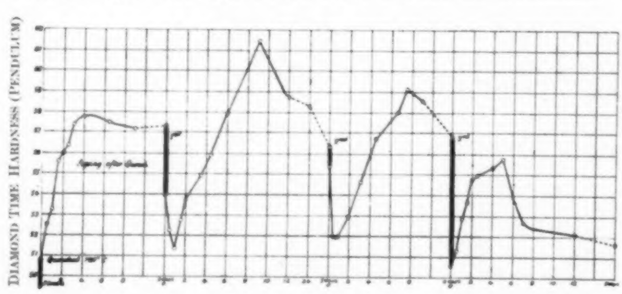


Fig. 3.—Steel (0.76 C., 0.59 Mn., 0.15 Si.) quenched from 780° C. aged; 1½ turn in magnetic field at 200° C.; aged. Repeated three times.

The specimen treated at 100° (Fig. 5) showed the fall, rise, fall sequence characteristic of the carbon steel similarly treated (Fig. 2), but in the sixth and subsequent cycles the sequence was reversed. In the specimen treated at 150°

(Fig. 6) there was likewise a change of sequence at the fifth cycle, the original fall, fall, rise becoming rise, rise, fall.

Further experiments were made with a view to ascertaining the most favourable temperature at which to apply the magnetic treatment to a high-speed steel containing carbon, 0·75, tungsten, 18; chromium, 3·5; vanadium, 1. All the specimens were cut from a single sawblade, which had been normally hardened many months previously at 1,300° and 575° C., and were given $1\frac{1}{4}$ turns (occupying about $1\frac{1}{2}$ minutes) in the magnetic field at various temperatures. The specimens were rotated at the bottom of a bath fixed to the magnet and containing water, oil, or fused salt, according to the temperature under investigation. The results of these experiments are given in Figs. 7, 8, and 9.

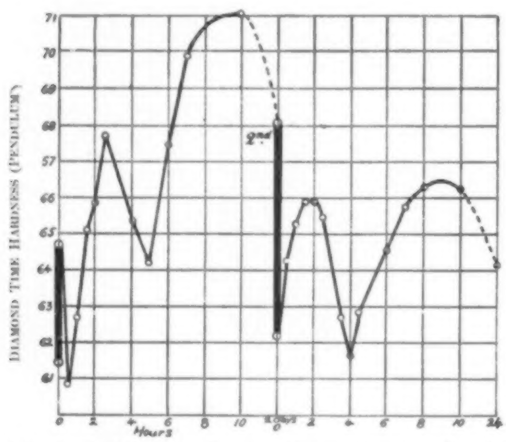


Fig. 4.—Safety Razor Blade: $1\frac{1}{4}$ turns in magnetic field; cold; Repeated.

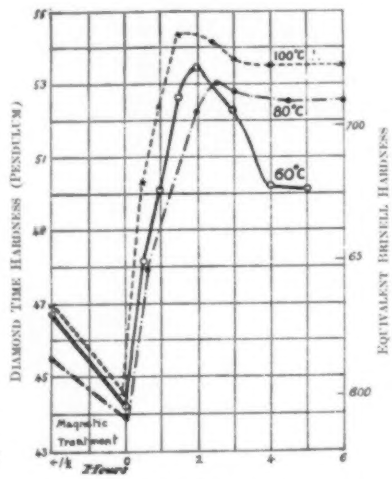


Fig. 7.—High-speed Steel: $1\frac{1}{4}$ turn in magnetic field at 60° C., 80° C., and 100 °C.

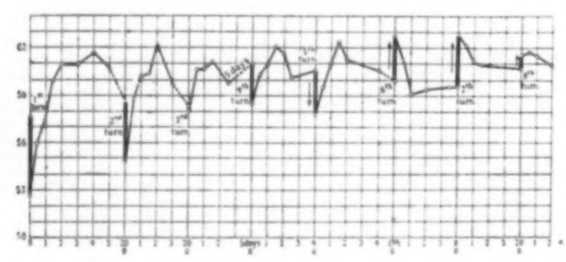


Fig. 5.—Safety Razor Blade. One turn in magnetic field at 100° C., repeated eight times.

Referring to Fig. 7, the sequence of hardness changes produced by magnetic treatment at 60°, 80°, and 100° C. is seen to be a fall, rise, fall; the final hardness being greatest in the specimen treated at 100° C.

In Fig. 9 are shown results of treatment at 240°, 270°, 320°, and 370° C., respectively. The remarkable feature of these results was the reversal of the sequence, which now became rise, fall, rise, as in the cases of hard carbon steel (Fig. 2), duralumin (Fig. 10), and brass (Fig. 11), after repeated magnetic treatment. The fall of hardness became more pronounced as the temperature was raised, and in the specimens treated at 320° and 370° C. was of a very marked character, culminating only after $3\frac{1}{2}$ hours' ageing, and being followed by a slow but very considerable rise. The sequence of hardness changes in the specimens treated at intermediate temperatures, 160° and 200° C., was different from that observed at lower and higher temperatures, being a rise, rise, fall, and this sequence was found also in specimens of the same steel treated at 180° and 220° C. respectively. In Fig. 8 the heavy lines show the results of treatment at 160° and 200° C., and in the dotted curves the results of one lower and one higher temperature are reproduced from Figs. 7 and 9.

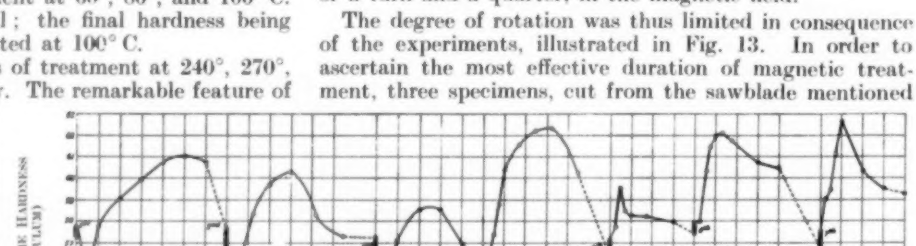


Fig. 6.—Safety Razor Blade: $1\frac{1}{4}$ turn in magnetic field at 150° C., and aged. Repeated seven times.

The three sequences—fall, rise, fall; rise, rise, fall; and rise, fall, rise—shown in Fig. 8 appear to be the most characteristic results of the magnetic treatment of hard and soft steels and non-ferrous metals, all these three sequences having been met with repeatedly in the very large number of experiments which have been carried out. It is noteworthy that all three sequences are found to occur, in the same order, in hard high-speed steel treated at increasing temperatures (Fig. 8), in duralumin repeatedly treated at room temperature (Fig. 10), and in brass similarly treated (Fig. 11).

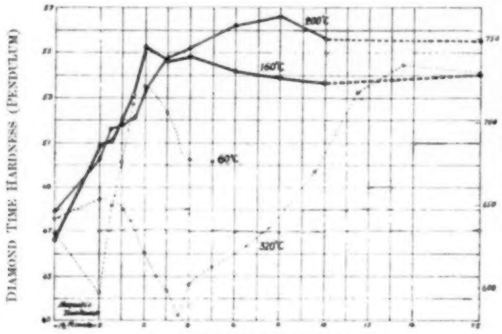
Further experiments were made with a modern high-speed steel (Osborn's S.O.B.V.) whose full analysis is not published, but which is stated by the makers to contain 18 to 20% of tungsten and a high percentage of cobalt.

Following the indications given in Fig. 8, a specimen of this steel, previously hardened by the makers, was subjected to magnetic treatment at 200° C., the intention being to produce the rise, rise, fall sequence, which had been found to result from treatment at 200° C. (see Fig. 8.) and which gave the highest ultimate hardness. This treatment applied to the cobalt steel resulted in the rise, fall, rise sequence, as shown in the lower curve in Fig. 12. As this sequence had been previously associated with an excessive temperature of treatment, a further specimen of the steel was magnetically treated at 150° C., and this gave the rise, rise, fall sequence in the upper curve in Fig. 12, and a satisfactory ultimate increase of hardness.

It must be inferred from the above that steels of different composition require treating at different temperatures to give the maximum hardening effect. The best results have been obtained by treating plain carbon steels at room temperature, ordinary high-speed steels at 200°, and cobalt high-speed steel at 150° C.; and it will be observed that in every case the treatment consisted of a single turn, or a turn and a quarter, in the magnetic field.

The degree of rotation was thus limited in consequence of the experiments, illustrated in Fig. 13. In order to ascertain the most effective duration of magnetic treatment, three specimens, cut from the sawblade mentioned above, were given 1 turn, 10 turns, and 100 turns, respectively, in the magnetic field at 100° C. In each case there was an initial decrease of hardness followed by an increase, but the final hardness attained after 1 turn and 100 turns was approximately the same, while the specimen which

had been given 10 turns attained a lower maximum. The reason for this comparative failure of the 10 turns was not known, but it was decided to repeat the magnetic treatment of this specimen, giving it a further 10 turns under the same conditions as before in the expectation that the



HOURS AFTER MAGNETIC TREATMENT.

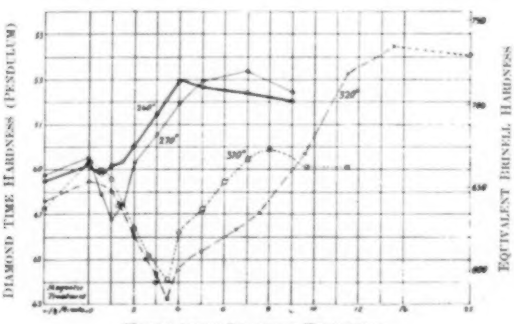
Fig. 8.—High-speed Steel: 1¼ turn in magnetic field at various temperatures.

hardness might thus be increased. The result, shown in Fig. 13, was quite other than had been anticipated. There was a great decrease of hardness, followed by an increase to a lower maximum than before. The experiment was repeated with the specimen which had been given 1 turn, with a similar result, a great fall in hardness followed by a rise to a lower maximum.

It was inferred, and the inference has been confirmed by much subsequent experiment, that the maximum hardening effect can be produced by a single turn in the magnetic field at a suitable temperature followed by a period of ageing. A greater number of turns, if continuous, and not interrupted by ageing, have little or no additional effect. If, however, a period of ageing intervenes, the subsequent treatment gives rise to a repetition of the original sequence of hardness changes, with, however, a tendency for the metal to become immune, the amplitude of the changes and the time period required for their completion both tending to decrease, as shown in Figs. 1 to 6.

The speed of rotation appears to have little or no influence on the results. Experiments have been made with periodicities ranging from 1 cycle in 20 minutes to 500,000 cycles per second. All were effective in setting up periodic hardness changes during subsequent ageing, and it was not possible to attribute any differences in the results to the influence of different speeds used in the magnetic treatment.

It was shown in the previous paper[3] that the two hardening processes, Cloudburst bombardment and the



HOURS AFTER MAGNETIC TREATMENT.

Fig. 9.—High-speed Steel: 1¼ turn in magnetic field at 240°, 270° 320°, and 370° C.

rotating magnetic field, are not merely alternative methods for increasing the hardness of steel, but that both processes may be applied to the same specimen, the hardening effect of the second process being superimposed on that of the first.

To investigate this matter further, a specimen of tungsten-cobalt high-speed steel which had been hardened by the makers was subjected first to Cloudburst and afterwards to magnetic treatment. The results are shown in Fig. 14. The specimen was first subjected to Cloudburst treatment by 3 mm. steel balls falling from heights of 3 and 4 m., which resulted in an immediate rise from 66·38 to 76·14 diamond time hardness. The specimen was then aged with periodical hardness tests, the hardness rising to 81·02 in 2 hours, and falling to 78·34 after the lapse of four days. The specimen was then given 1¼ turns in the magnetic field at 150° C., this process occupying 1½ minutes after the specimen had attained the temperature of the bath. This resulted, as before, in the rise, rise, fall sequence of hardness changes; the combined effects of the Cloudburst and magnetic treatments being a rise in hardness from 66·38 to 85·32, equivalent by conversion to an increase from 895 to 1,150 Brinell.

It is significant that the rise, rise, fall sequence occurred not only after the magnetic treatment, but that the same sequence resulted from the Cloudburst treatment. The extended application of the technique of half-hourly

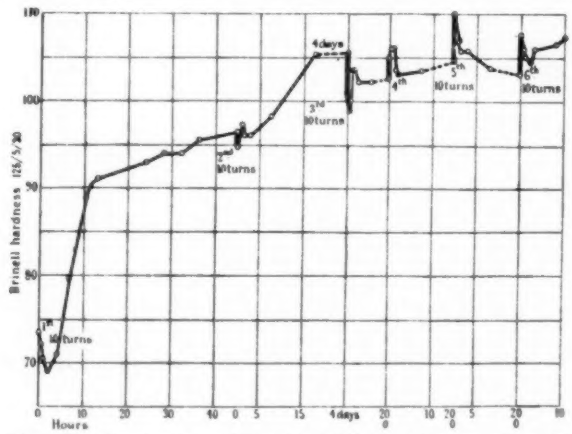


Fig. 10.—Duralumin. Quenched 500° C. 10 slow turns in magnetic field, repeated six times.

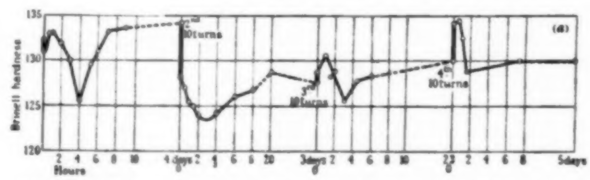


Fig. 11.—Rod Brass. Ten slow turns in magnetic field, repeated four times.

hardness tests has indeed shown this sequence of hardness changes to be of frequent occurrence during the ageing of metals after hardening. It is seen to have occurred in carbon steel hardened by quenching (Figs. 1, 2, and 3). It has been found in duralumin, aged after quenching from 500° C., in duralumin aged after rolling, in soft carbon steel aged after Cloudburst bombardment, and in work-hardened steel subjected to low-temperature annealing, the tests in the last case having been made on the hot specimen while actually in the annealing furnace.

Hot-hardness of Magnetically Treated Steel.—It is now generally recognised that hardness tests applied to tool steel in the cold state can give no adequate indication of its efficiency in cutting metals, and the reason is not far to seek. It has been shown[4] that tools when cutting metal, even when flooded with a cooling medium, may generate temperatures approaching or exceeding the softening point of the steel, and it is obvious that no test applied to the cold steel can indicate its properties or its probable behaviour when cutting at a high temperature. Such information can only be obtained by testing the steel hot, either by actual cutting tests or by hot-hardness tests.

In order to investigate the heat-resisting properties of steel treated by the magnetic process, and by a combination of the magnetic and Cloudburst processes, specimens of steel so treated were tested with the pendulum at temperatures rising by stages of about 20° C. from room temperature to the softening temperature. The hot-hardness tests were made without removing the specimen from the electric furnace, four tests being made at each temperature, and the whole determination occupying about five hours in each case.

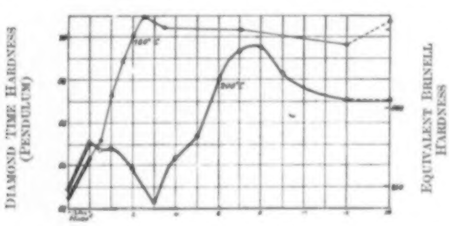


Fig. 12.—Cobalt High-speed Steel: 1¼ turn in magnetic field, at 150° and 200° C.

In Fig. 15 are shown results of hot-hardness tests on the treated steels, and, for comparison, some previously published hot-hardness curves have been incorporated in the same diagram. The lowest curve is that of one of the modern cobalt high-speed steels (Osborn's), as hardened by the makers, and is reproduced from a report[5] published in 1930. The next curve is from a specimen of the same steel hardened by the makers, and magnetically treated at 150° C. (Fig. 12). The next curve is from the same steel similarly hardened, and afterwards superhardened by Cloudburst treatment; it is reproduced from the report referred to. The top curve is from the specimen of the same steel which had received, first Cloudburst, and afterwards magnetic, treatment, as shown in Fig. 14.

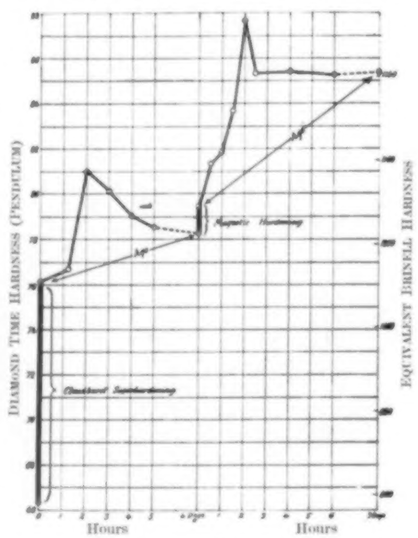


Fig. 14.—Cobalt High-speed Steel superhardened by Cloudburst; Aged; 1¼ turn in magnetic field at 150°C., and again aged.

The hot-hardness curves in Fig. 15 indicate the possibility of a great advance in the efficiency of cutting tools. It was shown in the report[5] that the cobalt high-speed steels are particularly susceptible to the Cloudburst superhardening process on account of their abnormally high work-hardening capacity, and that tools so treated were 84% more durable than tools similarly hardened but not superhardened. It was shown that these steels, when cutting under some conditions, are superhardened by the abrasive action of the chip, and there is reason to believe that their ability to cut metals of great hardness, approaching or even exceeding that of the tool itself, is due to this circumstance. Superhardening by chip abrasion is not likely to occur to any marked extent in the cutting of the softer metals such as mild steel, and in practice the cobalt steels have shown less advantage over the older tungsten steels in the cutting of softer metals.

It has now been shown that full advantage can be taken of the work-hardening properties of the cobalt steels, even when superhardening by chip abrasion may not be expected to occur, by superhardening the top surface of the tool by Cloudburst bombardment. It has, further, been shown that a like increase in the cold-hardness and hot-hardness of these steels can be effected by means of the magnetic treatment, and that the two processes may be used in combination to produce a degree of hardness, both cold and at high temperatures, such as has never before been attained in steel.

The choice of the process or processes with which to treat any given class of tool or other article of hard steel will depend on special circumstances. The magnetic process is applicable to tools or other articles of any degree of complication. The best results hitherto have been attained by treatment occupying not more than 2 minutes, at temperatures not higher than 200° C., the full hardness developing after ageing for from 3 to 5 hours. The Cloudburst process has been found especially applicable to articles of simple form, such as lathe tools, which are treated on the top face only, and to parts which are required to withstand severe abrasion, such as cams, tappets, and gearwheels of motor-cars. The hardness produced by the Cloudburst is higher than that resulting from magnetic treatment alone, but it has been shown that the combined effect of the two processes is greater than that of either taken separately.

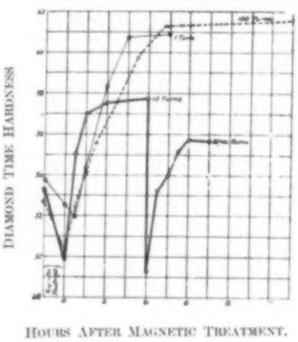


Fig. 13.—High-speed Steel: Magnetic treatment at 100° C. Effect of one turn, ten turns, and one hundred turns. Effect of repetition after ageing.

No explanation can yet be given of the newly discovered magnetic phenomena here described. The familiar metallurgical explanations based on precipitation, recrystallisation, and so forth, appear to be entirely inadequate. Rather must these phenomena be held to be manifestations of that fundamental metallurgy which underlies the familiar subdivisions and groupings of metallic constituents, and treats metals simply as agglomerations of atoms in crystalline form. Other manifestations of fundamental metallurgy are the phenomena of slip on deformation, of work-hardening, of the sequence of low-temperature changes to which the author has been directing attention for many years[2, 6, 7, 8] of age-hardening after deformation[2], and the "P_3 anneal"[2, 8]. If the changes in hardness should prove to be atomic in character, the question will arise whether the rotating magnetic field affects the internal structure of the atoms or only their arrangement in the space lattice. In the former case, perhaps in either, there seems to be no valid reason why the reactions should not occur in agglomerations of atoms quite outside the range of metals. Experiments are in progress which may throw light on these wider possibilities.

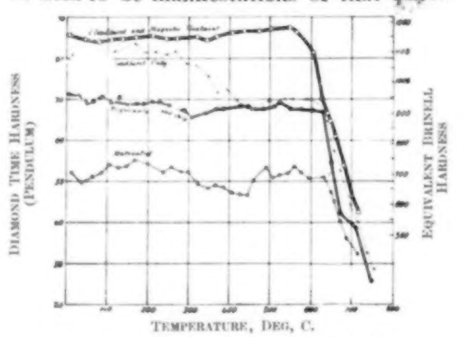


Fig. 15.—Hot-hardness of Cobalt High-speed Steel. Effects of Cloudburst and magnetic treatments separately and combined.

It seems desirable to set down at this juncture, in the most general terms, the hypothesis which the author has provisionally adopted, namely, that the rotating magnetic field gives rise to a precession or like fluctuation of a periodic character in the systems of electrons, which, in turn, causes periodic fluctuations in molecular cohesion.

This hypothesis has suggested several avenues for further research, and these are now in process of exploration. The evidence is not yet complete, but some indication may be given of the nature of the investigations, and of the conclusions towards which they are pointing.

If the magnetic treatment gives rise to periodic fluctuations in cohesion, these should be revealed not only in hardness fluctuations, of which there is abundant evidence, but in related fluctuations in other physical properties of the metals. Experiments have shown marked fluctuations in the ductility of certain metals after treatment with the rotating field, the fluctuations being periodic, and synchronising closely with the hardness fluctuations.

Further, it might be anticipated that periodic fluctuations occurring in the elementary magnets of which the metal is built up should give rise to periodic fluctuations in the resultant magnetism of the body as a whole. There is experimental evidence that such periodic fluctuations do in fact occur.

If the rotating magnetic field is capable of setting up periodic fluctuations in the electronic systems, might it not be possible, by other than magnetic means, to set up fluctuations of this character? There is already a considerable and growing body of evidence that fluctuations of hardness are set up by the processes of quenching from high temperatures, and of mechanical deformation. Evidence of both is contained in the present article, and the similarity between these fluctuations and those set up by the magnetic treatment is such as to suggest strongly that they too are periodic in character and similar in origin. The changes in ductility which occur in freshly hardened tool steel are well known, and of more than theoretical interest. Tools which have become warped in hardening are known to pass through a temporary phase of ductility such that they can be easily straightened by bending.

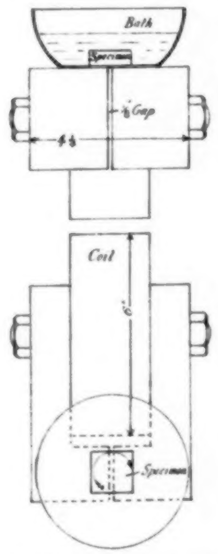


Fig. 17.—Electro-magnet with bath and specimen in position for treatment.

NOTE.—In an investigation of the hysteresis losses in soft iron and hard steel in rotating magnetic fields, Professor F. G. Baily showed (Phil Trans., A. 738, 1896) that the loss attains a maximum when the induction is between 14,000 and 17,000 C.G.S. lines of force, tending towards zero values in weaker and stronger fields. It so happens that the fields used in the experiments here described coincide exactly in strength with Baily's critical range. It is therefore possible, though it has yet to be established, that these phenomena only occur in magnetic fields whose strength lies between certain critical values.

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Precious Metal Refinery.

Extensions at Acton Works.

AN event of considerable importance, not only to this country but to the whole of the British Empire, took place on April 23, when extensions to the Acton Precious Metals Refinery of the Mond Nickel Co., Ltd., were opened in the presence of a number of distinguished guests, including the Hon. G. Howard Ferguson, LL.D., High Commissioner of Canada, and the Rt. Hon. J. H. Thomas, M.P., Secretary of State for the Dominions. The Rt. Hon. Lord Weir, P.C., presiding over the inaugural luncheon, said that the present extension would make this plant the largest precious metals refinery in the world, capable of handling a dominating percentage of the world's present needs of platinum metals, which played an increasingly important part in the most modern industrial progress, particularly in electrical development. Vast refineries for nickel and copper had been established in Ontario by the International Nickel Company of Canada, Ltd., and now a similar enterprise was being started in England to deal with the treatment of precious metals, treatment involving the highest degree of metallurgical skill. Platinum is much more than a luxury metal, and is, indeed, an essential to many industries, so that a large and assured supply is vital to the Empire. Such a supply can be obtained in the refining of nickel-copper ores, and when the nickel plant is in full operation in the Sudbury district of Ontario it is expected that about 300,000 ounces per annum of platinum metals will be obtained from this source.

The original refinery at Acton was built in 1924, and was used for the recovery of platinum metals from the rich concentrates produced by the carbonyl process of nickel extraction. Later, crude platinum from South Africa was also treated. More recently still, since the fusion of the interests of the International Nickel Co. Inc., and the Mond Nickel Co., Ltd. the treatment of concentrates from the electrolytic nickel refinery at Port Colborne, in Ontario, has been undertaken at Acton.

The metallurgical equipment of the refinery is on a much smaller scale and is more diversified than that found in the average heavy metallurgical works. An interesting feature is that the methods employed in the assay, chemical, and electrolytic laboratory are on a production scale.

Smelting and cupellation are carried out in small basic-lined tilting furnaces. Chemical stone ware, vitreosil, porcelain, glass, hard and soft rubber, chemical asphalt, and lead are employed for plant construction, while wood and iron vessels, suitably lined, may be used.

One of the features of the works is the equipment of the wet process buildings, which is arranged on a series of terraces constructed in acid-proof materials; this arrangement allows flow of liquids by gravity and reduces labour and supervision. The usual supply services of water, steam, electricity, gas, vacuum, and compressed air are laid on throughout, and an overhead crane facilitates the removal or replacement of plant.

The process of refining is a very elaborate one, for it involves the separation of seven distinct metals one from another, and also from fifteen base metals.

The concentrate or residue from the nickel extraction process contains a fairly large proportion of silver and of lead. This is first smelted, the lead being used as a collector of the precious metals. The excess of lead is then removed, leaving a silver-rich precious metals alloy, which is parted with sulphuric acid. Subsequent treatment dissolves most of the platinum, palladium, and gold, the platinum being precipitated as ammonium platinichloride and the palladium as palladosammine chloride, yielding pure platinum sponge and palladium sponge respectively. Both the silver and gold are purified by electrolysis, the methods adopted being selected for the recovery of any trace of platinum metals and for the elimination of any trace of base metals. Rhodium, ruthenium, and iridium are then concentrated by remelting the insolubles and residues of the wet process. The precious metal alloy is then returned for wet process treatment and final purification in a special department.

The Progress of Power Production.

The twenty-first annual May Lecture of the Institute of Metals was delivered recently by Mr. W. B. Woodhouse, Past-President of the Institution of Electrical Engineers and engineer and manager of the Yorkshire Electric Power Co.

Mr. Woodhouse reviewed the development of power production throughout the world, and in particular the important question of the extent to which this country, dependent as it is on coal for power production, can compete with other countries in the production of cheap electricity by water power for metallurgical and other industrial purposes. Electrical methods of treating ores and of producing and refining metals are used to an extent which requires very large amounts of power, and which is rapidly growing; the industrial importance of carrying on such operations in this country was emphasised by the lecturer. A review of the progress of the steam engine from the days of James Watt in 1782, and an analysis of the costs of production in a modern electric power station on a large scale show the great improvements which have been made in recent years and indicate the prospects of further reductions; electric power is being produced in this country by the consumption of coal at a price which compares favourably with water power in other countries. The great development of water power in other countries, and the large amount still unused, calls for the most careful consideration of our relative position as a power-producing country.

The lecturer next considered the use of oil fuel, its effect on the production and demand for coal, the prospects of producing oil fuel from British coal being also discussed. The successful distillation of coal to produce oils would be greatly facilitated were it possible to use metal retorts in place of refractory materials at temperatures of about 1,000° F., and he also stated that the efficiency of steam-power stations would be increased if such a working temperature were practicable. Thus in a twofold way the future of the coal industry is dependent on the metallurgist.

A comparison of the competitive sources of power with the production of power from coal in this country leads to the conclusion that this country, due to the great engineering developments of recent years, is in a position to compete in the production of cheap electric power in large quantities for metallurgical purposes with countries dependent on water power. The other substantial advantages of this country as a site for such industries lead the lecturer to the conclusion that not only in ordinary industrial processes but in many electro-chemical and thermal processes in which the cost of electric power is a major part of the cost of production this country will continue to be found an admirable workshop for the world.

The progress of electric power supply by a single organisation over a wide area initiated in this country some thirty years ago by the electric power companies, whose developments have, in the face of great difficulties, provided a general supply of electricity at a low price, is shown to have led the way to nationally and internationally interconnected systems of supply in all parts of the world, and in this country to the establishment of the "grid" by the Central Electricity Board.

In discussing the price of electric power the lecturer indicated the practicability of obtaining large amounts of electricity from efficient power stations in this country at a price as low as one-fifth of a penny a unit or even less for secondary power or restricted supplies. But, though the cost of power is in itself of great importance, it is only one item of many in the total cost of manufactured products, and there seems every reason to think that not only in ordinary industrial processes, but also in many electro-chemical and thermal processes, in which the cost of electric power forms a major part of the cost of production, Great Britain will continue to be found an admirable workshop for the world.

Creep-Resisting Steel.

A Recently Developed Steel of Easy Workability.

Rapid developments in the use of high steam pressures and high degrees of superheat have created a demand for materials which will preserve their physical properties at high temperatures. Steels stressed under such conditions are liable to continuous elongation or "creep," and just as non-scaling steels have been developed for heat-resistance purposes it is necessary that creep-resisting steels should be available.

Considerable research work directed towards this end has been in progress in the laboratories of the United Steel Companies, Ltd., and after long efforts, a type of creep-resisting steel has been evolved which has been called "Durohete." In addition to tests carried out in this company's laboratories, a series of tests have been made by the National Physical Laboratory to determine the creep-resisting properties of this recently developed steel, and the report shows that the creep rate after 20 days under high stress and a temperature of 480° C. was less than 10^{-7} in. per hour. Other tests indicate that at a temperature of 480° C. the limiting creep stress of "Durohete" is approximately 18 tons per sq. inch. The tests refer to samples oil-quenched from 840° C., and tempered at 610° C., giving the following properties at normal temperatures :—

Max. Stress Tons sq. in.	Yield Point Tons sq. in.	Elongation % on 2 in.	Reduction of Area.	Izod Value.
69.3	62.3	17.5	55.0	55

The coefficient of expansion of the material, which is so important for certain components, and which should not be appreciably different from that of the material forming other parts of the structure, has been determined by the National Physical Laboratory and indicates that there is no material difference from the coefficient of expansion of ordinary carbon steel, the figures being :—

Temperature Interval.	Mean Coefficient of Expansion per 1° C.
0° – 200° C.	.0000125
0° – 300° C.	.0000130
0° – 450° C.	.0000136

One outstanding feature of this creep-resisting steel is its relatively easy workability in all forms, and it is stated that its cost brings it within the bounds of practical use on an extensive scale.

Grinding Bolts in a Centreless Machine.

The suitability of centreless grinding machines for rapid and accurate grinding of bolts has been demonstrated by the Churchill Machine Tool Co., Ltd. A batch of hexagonal-headed bolts, ½ in. diameter and 2 in. long, were recently ground at a speed which illustrates the value of these machines for this class of work. The operation consisted in grinding the shank and face under the head, and this was performed at a production rate of 900 per hour, removing 0·010 in. from the diameter.

Work in centreless grinders is accomplished by one of two primary methods. One is the through-feed method, in which the work passes axially from one side of the machine to the other. This method is for straight cylindrical work. In the case of taper, form, or shoulder work, the infeed method is preferable. This method consists in introducing the work either vertically or laterally into the grinding throat, steadying it in position during the grinding operation, and subsequently ejecting the work from the grinding throat. This latter method was used in grinding the bolts, the work being done on a No. 2 Churchill-Cincinnati centreless grinder.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part VII.—Ingot Pouring Practice.

Practice employed in pouring aluminium rolling ingots in various types of moulds is discussed in this article.

As stated in a previous article, the quality of aluminium sheet is very considerably dependent on the quality of the original ingot from which rolled. Various ingot defects which cause trouble in rolling, or ultimate rejection of sheet on inspection, are directly associated with the technique of pouring. Unfortunately, the pouring of good rolling ingots is still something of an art, quite aside from the control of such operating variables as mould and pouring temperatures, pouring rates, and cooling rates. These variables are intimately interrelated, and are also related to the mould design: in practice, they cannot ordinarily be controlled within the limits desired. Hence, in order to compensate for irregularities, manipulative skill is requisite in the production of satisfactory rolling ingots. This refers more especially to pouring in tilting, vertical book moulds—the type used largely in aluminium work. However, regardless of the type of mould, sloppy pouring, which causes splashing, uneven or irregular pouring, and improper heading give rise to poor ingots.

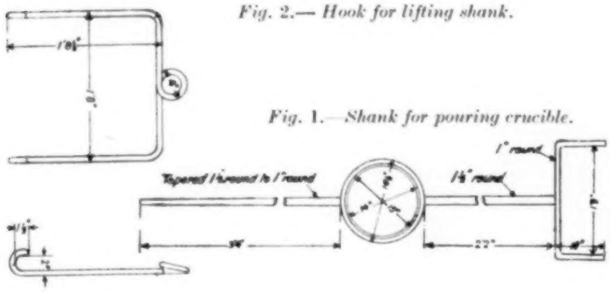


Fig. 2.—Hook for lifting shank.

Fig. 1.—Shank for pouring crucible.

Not unnaturally, the aim of mill operators has been to eliminate the necessity for skill in pouring by attempting to control the sundry variables and by utilising various mechanical and semi-mechanical mould-operating contrivances and pouring devices. Obviously, the necessity for a high degree of skill in any tonnage operation is generally disadvantageous, first, by reason of its dependence on the unreliable human element, and second, because it presupposes increased labour costs. Apart from the final heading, it appears that the least dependence on the human element would be had with some adaptation of the Durville method. So far, however, this method has not found favour for the production of aluminium rolling ingots. In the operation of tilting, vertical book moulds there is no gainsaying the necessity for skill in pouring. On the other hand, when aluminium ingots are cast in non-tilting, stationary moulds—*i.e.*, the flat, open type and the vertical, edgewise-on type—there are certain undesirable features inherently present in the operation which no degree of pouring skill can possibly overcome.

It is generally agreed that in pouring aluminium rolling ingots the metal should enter the mould cavity with a minimum of turbulence. Agitation is plainly at a minimum when the metal flows slowly down the narrow face of a steeply tilted mould, the lip of the pouring ladle serving in effect as a prolongation of the face. The head of metal is also at a minimum, and this process of pouring is a close approximation to the Durville method. When poured into stationary moulds of the flat or vertical type, more or less splashing, caused by the initial slop of metal in dropping from a height, occurs. The splashing is more the greater the height, and is less the more the skill in pouring. Assuming satisfactory grade of metal and conditions of melting, ingots which have been properly poured in tilting, vertical book moulds, although not perfect, are usually of satisfactory quality for practical purposes. Other things being equal, ingots poured in non-tilting, stationary moulds are more prone to be defective.

In the present article, current practice in pouring aluminium rolling ingots in various types of moulds is discussed, the operation of tilting, vertical book moulds being taken up in detail. Some attention is given to the influence of several variable factors on the pouring operation and on the quality of ingots. Emphasis is laid on the importance of proper pouring rates, correct feeding, and the prevention of splashing in the mould cavity. Appliances used in pouring and in handling ingots are described. Finally, the utilisation of mechanical equipment in pouring and in mould operation and its relation to man-power requirements in ingot production are discussed.

Pouring Ladles and Appliances.

The vessel used for containing the liquid metal in the pouring operation may be either a graphite-clay crucible or a thin cast-iron pot. In casting ingots of fair size it is usual practice to draw off sufficient metal to fill only one mould, the ladle then being returned to the furnace and refilled for the next pour. Accordingly, the capacity of the pouring vessel is chosen to suit the size of ingot being cast. Thus, a crucible holding about 150 lb. of metal may be used to pour ingots weighing 100 lb. to 120 lb. One object of pouring only one ingot and then replenishing the ladle, rather than pouring several ingots from the same pot, is that close control of the temperature may be had. Moreover, large pouring ladles are troublesome to handle, and tend to cause splashing of metal in the operation. Of course, as a practical matter, when rather small ingots are cast, two or more may be poured from the ladle before refilling.

Preferred practice calls for the use of an insulated pouring ladle. In one design the vessel consists of a thin cast-iron pot covered with a layer of insulating material about 1-in. thick. This is housed with sheet steel. An insulated sheet-steel cover is fitted over the top, a hole being provided at the pouring lip for egress of metal. Pouring temperatures can be controlled with satisfactory precision by the use of an insulated ladle. At the same time the metal may be held in the furnace at a lower temperature than when a non-insulated ladle is used, because the drop in temperature between the furnace and the mould line-up is less. Also irregularities, due to heat losses, are reduced by using insulated and covered ladles.

Filling and Handling Ladles.

Pouring ladles may be filled by ladling metal from the furnace, tapping, or tilting, depending on the design of melting equipment. Ladles should be preheated before the start of pouring. In transporting ladles back and forth between the furnace and the moulds, they may be carried by hand or by overhead mono-rail with chain-hoist suspension. Ladles are mounted in shanks. When moved by mono-rail, a suitable shank hook is provided for lifting by the hoist. Fig. 1 shows a shank for holding a No. 150 crucible, and Fig. 2 shows a shank hook.

At one plant, in pouring from tapping-type, stationary-hearth furnaces, the ladle is placed in position beneath the runner, the plug is pulled, sufficient metal is allowed to flow, and the tap-hole is replugged. The metal is then fluxed and skimmed, whereupon the ladle is pulled up with the hoist and moved to the mould line-up by overhead mono-rail. Stationary furnaces may be conveniently tapped and plugged by the use of a special tool. This consists of a truncated cone of cast iron attached to a handle. A slightly damp ball, made of 50 : 50 dough-asbestos, or other suitable mix, is stuck on the end of the

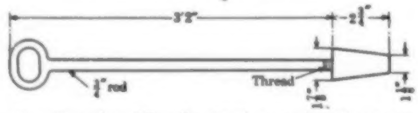


Fig. 3.—Tapping Plug for Stationary-hearth Furnace.

plug. Fig. 3 shows a form of tapping plug. In the operation of stationary-hearth furnaces, the tap-hole tends to become encrusted and normally requires cleaning after the plug is pulled. A convenient tool for cleaning the hole, and thereby giving a free flow of metal, is shown in Fig. 4. This tool, called a tapping needle, is made simply by drawing a steel

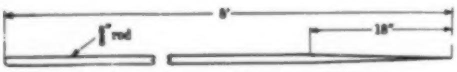


Fig. 4.—Tapping Needle for Cleaning.

bar out to a sharp point at one end. The bar is poked in and out through the tap-hole in cleaning.

Fig. 5 shows the operation of tapping from a hearth furnace, using a graphite-clay crucible for pouring. The crucible is mounted in the shank, the latter resting across the pit ; the shank hook will be noticed in the right foreground. The furnace tender is seen, at the left, standing with a plug to shut off the metal flow.

In production layouts, one pouring ladle serves one line-up of, say, 10 moulds, the moulds being used in rotation. One or two men, depending on the number of mould line-ups being served, are employed at the furnace for tapping. One or two men, depending on the equipment used, are employed at each mould line-up for pouring. Two men are required for pouring into book moulds when the ladle is not affixed to the mould.

Pouring in Non-tilting Moulds.

As described in a previous article, non-tilting ingot moulds are of two main types, viz., stationary and screw-operated. Flat, open (horizontal) moulds of the stationary type are usually poured by hand from a ladle. Stationary, edgewise-on moulds and vertical, screw-operated moulds are poured from a ladle and also directly from the melting furnace.

In casting aluminium ingots in flat, open moulds, the ladle is brought to the bench or line-up, and the metal is poured in slowly until the mould is full, care being taken to avoid splashing. The surface of the liquid metal in the mould may then be skimmed to remove any scum. Liquid metal may be fed to the centre shrinkage cavity as freezing proceeds. In one plant where ingots weighing about 40 lb. are cast in this type of mould, the contraction face is not fed. If the moulds are mounted on a turn-over bench the ingots are removed when frozen by inverting the bench ; ingots which do not fall out are loosened by bumping the mould with a sledge-hammer. If mounted on a rigid table structure the moulds may be thrown over upside down, the ingots loosening and remaining on the table plate when the moulds are picked up. Ingots may also be removed from flat, open moulds by driving the pointed ends of a double hook into the top face and pulling up with a light chain hoist. At the plant above alluded to, two 40-lb. ingots are poured from a graphite-clay crucible holding about 100 lb. of metal, and then the pot is refilled.

Ingots may be poured in stationary, edgewise-on moulds in the same way as just described for the flat, open moulds. Methods of mounting the moulds and removing the ingots when frozen may also be the same. Edgewise-on ingots are normally fed at the head in order to counteract the piping effect which is greater than in ingots cast in flat moulds.

At one plant edgewise-on ingots are poured directly from a tapping-type, stationary-hearth furnace of large capacity. The moulds are mounted on small buggies, which run on a narrow-gauge track. Each buggy holds five moulds. The main track is laid parallel with the tapping wall of the furnace, and is arranged with suitable switching. When ready to pour, a buggy full of moulds is brought up into position so that the first mould is in line with the tap-hole. A pivoted runner is attached to the main tapping runner of the furnace, and the former is allowed to rest on the mould. The plug is pulled and the metal flows down the runners and into the mould. When the mould is full the furnace tender shifts the movable runner to the next mould, and moves the buggy slightly along the track, so that the second mould is in line with the tap-hole. As the second mould is filling, liquid metal is fed to the head of the first mould with a small hand ladle, this metal being scooped from the runner stream. The operation proceeds as described until the furnace has been emptied or until a sufficient number of ingots have been cast. One buggy after another is brought up into position, and the pouring is continuous. Of course, the operation may be stopped at any time when desired by plugging the furnace. The frozen hot ingots are removed from the moulds by driving the pointed ends of a double hook into the top edge and lifting up with a hoist. In this plant the ingots are preheated before rolling, and are stacked in piles preparatory to being sent to the preheating furnace.

As might be expected, considerable splashing of metal occurs in pouring by this method. The pouring rate is variable, due to the changing head of metal in the furnace, and dross inclusions are likely to be found in the ingots. It has been proved that sheet rolled from ingots poured by

Fig. 5.—Tapping from Hearth Furnace into a pouring crucible.

this method is of inferior quality. The chief advantage lies, of course, in the low labour costs of pouring.

At another plant, aluminium-alloy ingots are poured directly from a tilting furnace into vertical-screw-operated moulds. In the operation the mould is raised on the screw so that the shutter face is open, and metal is introduced at the bottom of the mould via a runner attached to the furnace pouring spout. The metal is poured in slowly, the mould being lowered on the screw. When full the ingot is fed at the head directly from the furnace or by ladle.

(*To be continued.*)

The Iron and Steel Institute

Annual General Meeting in London.

THE annual meeting of the Iron and Steel Institute was held at the Institution of Civil Engineers on May 7 and 8. Following the usual preliminary business meeting and election of new members, the newly elected president, Col. Sir Charles Wright, K.B.E., C.B., was inducted to the chair by the retiring president, Professor Louis, and his first duty was to present the Bessemer Gold Medal to Sir Harold Carpenter, F.R.S. In doing so he paid generous tribute to Sir Harold, and said the Iron and Steel Institute recognised the great value of his many scientific researches, his unselfish efforts in creating a greater appreciation of the importance of the application of science to the industries of the country, and the wonderful influence he had had in stimulating and encouraging an interest in the subject, and infusing a similar spirit of enthusiasm for research in the minds of so many workers.

In thanking his colleagues on the Council for the honour conferred upon him, and the members present for the manner in which they had received the remarks of the president, Sir Harold Carpenter referred to his work in the field of metallography, and stated that this science had become a part of steel metallurgy. He predicted that metallurgy of the future would have to get closer than it had already done to modern physics. In concluding, he paid tribute to those who had actively assisted him in his work, and had thus helped him to win this coveted distinction.

Sir Charles Wright, in his presidential address, dealt with certain phases of the Welsh tin-plate industry, and claimed that Great Britain had been the undisputed pioneer of this industry, while South Wales could be acclaimed as its home. In tracing the development of the industry, he said, one is bound to be impressed with its alternations of progress and setback, which reveal the economic and political upheavals that have taken place in various parts of the world during the last two centuries. Great emphasis was laid on the fact that, while the adjustment of supply and demand continues to be a most important factor in the trade, the future of the industry must depend on its ability to keep pace with scientific developments. If the industry is to be dynamic, it must continue to pay attention to technical research in all its branches; it cannot afford to be stagnant when the competition of other countries shows that this country no longer holds a monopoly of this specialised trade.

In addition to scientific developments, the future of this industry is bound up with considerations of orderly marketing, and Sir Charles referred to the arrangement between the Welsh and American tin-plate manufacturers, whereby, for a period of years, it was agreed that the combined export of tin-plates to certain markets should be distributed between the two countries in a fixed ratio. In his concluding remarks, he pointed out that the problem of expansion is bound up with organised marketing. Although he did not think home consumption could be developed to the same extent as in America, he felt that the development of home canning would have an important bearing on the future of the tin-plate industry. It may possibly enable plants to run at full capacity, which would allow profits sufficient to embark on capital schemes in keeping with modern tendencies and practice. But organised marketing must mean far more than the mere fostering of new markets; it must mean the creation of new outlets for tin-plates and the sinking of personal rivalries in the desire for a more rational organisation of the industry.

At the conclusion of the president's address a short session was held for the presentation and discussion of papers, further papers being presented and discussed at subsequent sessions. Apart from the report on Corrosion, to which reference is made on page 7, summaries of the subjects considered are given in their order of presentation.

Production Economy in Iron and Steel Works.

By DR. ING. OTTO CROMBERG.

The changes in the economic conditions in German industry brought about by the war has necessitated a fundamental study of the economic laws of factory management in regard to the operations involved in the manufacture of the finished products, and in a paper on this subject the author discussed the scientific organisation of manufacturing operations. Only the first part of the paper was presented at this meeting, the second part, being in course of translation, is likely to be presented at the autumn meeting. The author stated that work should commence with inspection of the material and the whole course of operations must be subdivided into the separate stages of manufacture, adopting the best possible method of operation at each stage. Not only is it necessary to follow the manufacturing operations under observation, but, in pursuing the study, consideration must be given to possible improvements and how they can be effected. The individual time occupied in the course of work may be exactly recorded, but the essence of time study consists in the appropriate analysis of the cycle of operations into its components, without regard at first to time requirements, the time records serving essentially as a standard of comparison in order, with the aid of costing on a time basis, to enable it to be judged which one, among possible methods of operation, is the most economical.

Different methods of carrying out time studies must be adopted according to whether the operation is performed by one man at one place, by one man at several places, or by a number of men at one place. The main point is always to determine accurately the relationship in time between the worker, the equipment available, and the material being manufactured, so that the optimum value of the cost of manufacture can be obtained. The author gave a number of examples of time study in various operations associated with the manufacture of wire, from which he obtained the time record of the cycle of operations from the heated billet to the winding of the rolled wire on the coilers. The output of the plant is calculated from the time within which one billet follows the next. The cycle of operations must then be analysed to find the shortest possible time at which pieces follow each other into the mill, so that the shortest possible interval can be determined in which the furnace can supply heated billets. A comparison of the values shows the longest interval and determines the stage in the production at which a bottleneck governs the output of the plant. Increasing the output of a mill necessitates eliminating the bottleneck from one of the operations, but the author asserts that a new bottleneck always occurs at some other operation. These studies undoubtedly lead to a lowering of production costs, providing the sources of loss revealed and defects in operation can be permanently eliminated, although the author points out that dangers may arise through wrong handling of a rigid works organisation and the recording of operations,

The Melting Shop of The Appleby Iron Co., Ltd.

By Arthur Robinson.

A detailed description is given of the plant and the process employed in the melting shop of the Appleby Iron Co., Ltd., at Scunthorpe. The ironstone available in the North Lincolnshire area is quarried cheaply, but it is a very poor quality, both chemically and physically, and very erratic in composition, the average iron content of the ore being 24%. Although pig iron is produced cheaply, allowance must be made for rapid variations in composition on account of the nature of the ore. The allowance is of greater magnitude than would be necessary in districts using a richer and more regular ore. The installation of furnaces and the process employed are designed to make the best use of the inferior quality of the ore. The process is arranged to use a large proportion of the iron produced, and in order to save casting expenses the iron is used in its molten state to make use of the heat.

The furnace equipment consists of four tilting furnaces comprising three 250-ton furnaces and a 300-ton furnace, with a 500-ton mixer placed centrally between them. Experience with both fixed and tilting furnaces has shown that the tilting furnace has a considerable advantage, both in speed and economy, when the bath of metal requires considerable refining, and that the large and deep baths allow a very fine control to be kept upon the composition and condition of the bath. The large mixer for storing the molten iron saves delays at the furnaces and excessive skulls in the ladles used for conveying the iron, and allows the blast furnaces to tap regularly. Irregularities in the composition of the molten iron are considerably reduced. A small amount of refining is done and any dirty scrap and offgrade can be melted.

The author described modern steelworks practice in its application to the conditions prevailing at Scunthorpe, and which he considers will bear comparison with any modern practice elsewhere. He expresses the hope that the information given will lead to more open interchange of information than has been possible in the past.

The Constitution of Scale.

By L. B. Pfeil, D.Sc., A.R.S.M.

A study of the fundamental facts associated with the oxidation of iron and steel was described in this paper. The investigation is a continuation of the author's study of the subject published in the *Journal of the Iron and Steel Institute*, 1929, No. 1. Although numerous references to the microstructure of iron oxide may be found in technical literature, apparently no systematic attempt has been made to explore the structure of compositions covering the range found in iron scale. The range of pure iron oxide compositions studied in this investigation was approximately 70 to 78% of iron, and it was necessary to adopt accurate analytical methods in order to give point to the experiments. The author regretted that more points were not available for use in the construction of an equilibrium diagram, but great difficulty was experienced in obtaining curves from mixtures of intermediate compositions, since slight changes in composition occurred during the melting operations, and the seven curves which are dealt with in this paper were spaced within a range of 4·5% of iron. The liquidus and solidus curves have been included in the equilibrium diagram although there is a lack of evidence. This diagram is in accordance with the microstructure of the system, and it is considered that the liquidus and solidus curves are approximately correct.

There are four phases in the range from 77·74 to 70·0% iron (FeO to Fe_2O_3)—viz., the ferric oxide phase, the magnetic phase, the ferrous phase, and the iron ferrous phase, and the field occupied by each is considered in detail. The author states that in the case of scale formed on steel containing elements such as manganese, chromium, silicon, nickel, and cobalt, the structure of the scale varies according to the distribution of the element in the scale. He is of the opinion that from the point of view of the improvement of heat-resisting steels, a study of the ternary oxide systems would be of great value.

Accelerated Cracking of Mild Steel under Repeated Bending.

By Walter Rosenhain, D.Sc., F.R.S., and A. J. Murphy, M.Sc.

In the course of investigations on a considerable number of failures in boiler plates and tubes, cases have been encountered in which evidence of damage has been found at points where local flexure may occur as a result of changes of pressure and temperature. In some instances the flexure, when it is extremely localised, may be severe enough to cause slight plastic deformation. This may occur just outside heavily reinforced riveted seams with the butt-straps, at or near flanges, and at or near the sharper bends in tubes. The type of failure or damage referred to is entirely distinct from the intercrystalline cracking which sometimes occurs in the vicinity of the rivet holes, while on the other hand the action of "fatigue" can scarcely be involved, since the number of flexures, even in the course of some years working would not amount to many thousands. Experiments have, in consequence, been undertaken, at the instigation of the Metallurgical Research Board of the Department of Scientific and Industrial Research, to investigate the effect of exposure to mildly corrosive liquids, of a type which might be present in a boiler, upon the endurance of samples of mild-steel boiler plate under repeated plastic bending.

This investigation, which is described in this paper, is based on experiments of an exploratory nature. The conditions, both of bending and of possible corrosion, were made severe in order to secure in a reasonably short time an approximate survey of the field. Much further investigation will be necessary to determine how far the effects of the same kind may be expected to occur in special conditions of boiler service. The results described are believed to be sufficiently important to indicate possible deleterious actions in mild steel which have not hitherto been suspected. They have been obtained under conditions very different from those prevailing in the operation of actual boilers, the principle differences being the severe strain imposed in these tests and the relatively low temperature at which the tests have been conducted. Further experiments are at present in progress with the object of following by microscopic means, the changes which occur on the surface of the test-piece during straining and resting in various media.

The Nature of Defective Laminations in Wrought-Iron Bars and Chain Links.

By H. G. Gough, M.B.E., D.Sc., Ph.D., and A. J. Murphy, M.Sc.

The fractured surface of a bar or chain link sometimes reveals the presence of one or more laminations exhibiting a brittle coarsely crystalline appearance, the remainder of the section having the normal appearance of ductile wrought iron. As the cause of the defect appeared to be obscure some investigation was considered desirable. By chance a 1 in. diameter bar, described by the suppliers as genuine treble best wrought iron, became available, which was found to contain a defective streak running along its entire length. The streak was approximately $\frac{1}{8}$ in. in thickness and extended across the full section of the bar. Mechanical tests, chemical analysis, microscopic investigation, etc., have been made on both defective and normal parts of the specimen and the results are detailed in a paper.

The investigation in regard to the nature of the defective layer led to the conclusions that the material forming this layer is slightly harder and much more brittle than normal iron. When broken, particularly under shock conditions, a coarsely crystalline fracture is exhibited. The layer contains very high proportions of phosphorus and silicon (phosphorus 0·48, and silicon 0·38%).

Microscopical investigation shows that the defective layer is not "burnt" in the sense of being oxidised. Compared with normal iron, it has a much coarser grain-size and larger slag inclusions. Rapid cooling, following heating to 1,050° C., produces no grain refinement in it, while the same treatment produces extensive recrystallisation in the normal material.

Thermal analysis shows that in the case of the defective layer, the transformation point is entirely suppressed. This important fact is ascribed to its high phosphorus and silicon contents. As a result, no grain refinement is produced by a "normalising" heat-treatment, but the coarse structure and dangerous brittleness of the material remained unaltered.

A consideration of the manufacturing processs suggests that the defective layer originate from abnormal puddled bars, which become worked into piles with normal bars.

The Effect of Carbon and Silicon on the Growth and Scaling of Grey Cast Iron.

By A. L. NORBURY, D.Sc., and E. MORGAN, M.Sc.

Irons containing 4 to 10% of silicon in conjunction with graphite in a finely divided condition are being developed commercially by the members of the British Cast Iron Research Association for growth and scale-resisting purposes. They have been protected by British and foreign patents held by the British Cast Iron Research Association and are registered under the name of "Silal."

In this paper are given the results of further investigations on the effect of carbon and silicon on the growth and scaling of grey cast iron. Results are given first of dilatometer tests on grey cast irons having total carbon contents between 4·0 and 2·1% and silicon contents between 1·6 and 7·6%. These tests show that as the silicon content is increased up to 3 or 4% the growth increases. The tests also show that with still higher contents of over 4%, the growth of irons, having not too large graphite flakes, decreases to a very small figure. This beneficial effect of high silicon content is partly due to its action in raising the critical point to a greater extent and to its marked effect in increasing the resistance to oxidation. Results are given of accelerated growth tests carried out by heating in moist CO_2 at 600°, 700°, 900°, and 1,000° C., irons having silicon contents between 0·7 and 14·6%, and total carbon contents between 4·0 and 1·0%. Increasing the silicon content is so effective that growth and scaling may be reduced to negligible quantities even under the most severe service conditions, provided that the silicon content is sufficiently high and that the iron is made in such a way that oxidising gases cannot penetrate below the surface. The authors point out, however, that these irons become increasingly brittle as the silicon content increases, and are not suitable for service conditions where there is rapid local heating and cooling, since under such conditions they are liable to crack. The authors conclude that in the high-silicon alloys the allotropic changes occur at such high temperatures, owing to the raising of the critical point, that the irons are ductile and do not crack when heated and cooled through these critical points, even though they are brittle at lower temperatures.

The Bessemer Process.

Some Considerations of its Possibilities in England.

By V. HARBORD, A.R.S.M., A.I.C.

Although the basic Bessemer process in Great Britain has been practically superseded by the basic open-hearth process, large quantities of basic Bessemer steel are being imported into this country at a lower price than we can produce open-hearth stee.l In the present state of our industry it is desirable to review the position in Great Britain and consider whether under present conditions the basic Bessemer process can compete with the Continent or produce at an appreciably lower cost than the open-hearth.

The object of this paper is to compare our material sources with those of the Continent, to promote discussion and arrive at facts likely to show the possibilities of producing cheap Bessemer steel in this country. Although the output of open-hearth steel has steadily increased on the Continent and now exceeds that of basic Bessemer steel, the production last year by the latter process exceeded 7,000,000 tons. The author discusses the main reasons for discontinuing the manufacture of basic Bessemer steel in Great Britain and is of the opinion that such a plant, to be successful, would have to restrict its production to mild steel, for such purposes as billets for re-rolling into miscellaneous semi-finished products. He considers four possible sites for a Bessemer plant in England and compares their possibilities with those on the Continent.

Factors in Blast-Furnace Operation and their Correlation.

By E. C. EVANS, B.Sc., F.I.C., L. REEVE, PH.D., and M. A. VERNON, M.A., PH.D.

In an earlier investigation by Evans and Bailey, an analysis was made of the operating results of over a hundred and twenty furnaces, and a method of correlation was developed which allowed of a quantitative expression of the factors entering into blast-furnace operation. The mathematical expression developed was as follows :—

$$C_1 + C_2 = \frac{500}{D} + [0{\cdot}4 + (0{\cdot}12 \times \%\,\mathrm{Si})] \times I + 0{\cdot}28S \quad (1)$$

where C_1 = lb. of carbon gasified at tuyères per sq. ft. of hearth area per hr. ; C_2 = sensible heat introduced with the blast, reckoned as equivalent lb. of carbon (burnt to CO) per sq. ft. of hearth area per hr. ; D = hearth diameter in feet ; I = lb. of iron made per sq. ft. of hearth area per hr. ; S = lb. of slag made per sq. ft. of hearth area per hr.

This expression was admittedly tentative in character and was not considered to do more than represent an actuarial average of furnaces examined.

It has been examined in the light of additional data and reported upon to the Blast Furnace Committee of the Iron and Steel Industrial Research Council. This report was presented in a paper at this meeting. The mathematical expression was confirmed with the modification, however, that the figure for carbon used, other than at the tuyères, has been calculated from the gas analyses wherever possible.

Arising out of the examination of over two hundred and twenty furnaces, the relationship between the iron factor and the time of stock descent has been determined with greater precision, and the relation for an individual furnace has been shown to be expressed by a curve of the hyperbolic type. This implies that after a certain output has been reached, advantages gained by further increasing the output are counterbalanced by increased hearth carbon requirements as expressed by the iron factor.

For the same time for stock descent the hearth carbon requirement, as expressed by the iron factor, are consistently lower with rich than with poor burdens, while the mean time of stock descent for optimum fuel consumption and output is lower with rich than with poor burdens—that is, a longer period of preparation in the shaft is necessary in the latter case.

The method has been used for the analysis of results of individual furnaces with a view to indicating factors limiting the efficiency of operation and for the prediction of results of new furnaces. The most important factor in blast-furnace efficiency is effective contact between ore and gas. This is influenced by the character of the burden, and

suggests the necessity of investigation into the most suitable treatment, particularly with reference to the improvement of coke quality and the treatment of the ore. The importance of the influence of moisture in the blast has been indicated by studies of an individual furnace over a period.

Radiation and external cooling losses in the shaft are higher in the winter than in the summer months, and investigations are desirable as to the advantages to be obtained from insulation.

The Sub-Crystalline Structure of Ferrite.

By Professor C. O. BANNISTER, M.ENG., A.R.S.M., and W. D. JONES, B.ENG.

During the microscopical examination of samples of wrought iron, some interesting features in the sub-structure of certain ferrite crystals have been observed. Three different types of these sub-crystalline structures are described and illustrated in this paper. The first type of structure is apparently associated with phosphorus in the metal. It has been found most easily and abundantly in specimens of wrought iron, but has also been found in mild steel. To some extent it is similar to the "coring" structure found in certain alloys and met with commonly in the 60/40 nickel copper alloy, and, like this coring, it affects considerable areas.

The second type of structure has been found in some specimens of rough iron in the bar form, but was most easily distinguished in specimens after annealing in an atmosphere of hydrogen for a considerable time. This structure consists of a distinct veining of the ferrite crystals. The third structure considered was a modification of the second type of structure or the result of continued etching of material containing the second type of structure. It has been found in wrought iron after prolonged etching with nitric acid, and is generally in the form of isolated crystals, although it sometimes affects a considerable area of the specimen as fine markings.

Some Alloys for use at High Temperatures.

Complex Iron-Nickel-Chromium Alloys.

By C. H. M. JENKINS, D.SC., A.R.S.M., and H. J. TAPSELL, A.C.G.I., A.M.I.MECH.E.

The investigations described in a paper were carried out in the Metallurgy and Engineering Departments of the National Physical Laboratory under the programme of the Committee on the Behaviour of Materials at High Temperatures appointed by the Department of Scientific and Industrial Research. This work forms a continuation of two previous papers on nickel-chromium and complex iron-nickel-chromium alloy, the first of which was by Dr. W. Rosenhain and Dr. Jenkins, while the second part was by the present authors and others, the results of which are summarised in this paper.

The objects of the investigation forming the basis of this paper are set out and dealt with in three sections: The first being to determine the effect of additions of carbon and silicon to a cast nickel-chromium-iron-tungsten alloy, which appears to possess favourable resistance to creep at 800° C., by mechanical tests and microscopical examination; secondly, to determine the effect of exposure of such alloys to a service temperature of 800° C., by means of microscopic examination, Brinell hardness measurements, and tensile tests. A series of tests to investigate the effect of exposure for a constant period at temperatures between 600° and 1,100° C., was also carried out; thirdly, a consideration of the phenomena encountered in the other two sections. The effect of composition and the results of short and prolonged stress tests at 800° C. were studied in relation to alloys containing: nickel, 30%; chromium, 30%; tungsten, 4%; iron-silicon-carbon, 36%. The greatest resistance to prolonged stress occurs in the alloy containing 1·5% of carbon and 1% of silicon. This alloy melts between 1,285° and 1,315° C.

As a result of exposure to temperatures between 600° and 1,100° C., the alloys of this type undergo an increase in Brinell hardness and a change in microstructure. The phenomena encountered explain the improvement in the mechanical properties of the quaternary alloys containing nickel, chromium, tungsten, and iron, resulting from the addition of carbon and silicon. The most suitable alloys for stress resistance appear to be those which maintain, after the initial period, a fairly constant Brinell hardness after exposure to high temperatures.

In view of the high proportion of nickel and chromium, these alloys remain in the austenitic condition throughout the temperature range between their melting points and atmospheric temperature. No hardening action of the type described in the paper can, therefore, be ascribed to the suppression of the transformation in iron. On the other hand, the addition of carbon to a ferritic steel is, in general, thought to cause a gradual but continuous increase in hardness. An alloy containing similar proportions of carbon, silicon, chromium, and nickel, but no tungsten, exhibits changes in microstructure similar to those of an alloy containing 4% of tungsten, but there is no appreciable increase in hardness on the heat-treatment of tungsten-free alloys, whereas on heat-treatment the tungsten-bearing alloys exhibit an increased hardness. The strength of the tungsten-free alloy under prolonged tensile tests is low.

The phenomena encountered in the present experiments, although rendered obscure owing to the number of metallic or other elements present at one time, bear in several of their aspects some resemblance to the changes often referred to as "age-hardening" in the alloys of aluminium—for instance, duralumin. In such age-hardening it is found that the hardness changes are practically complete before visible separation of new constituents is detectable under the microscope. In the present instance the hardness changes appear to occur contemporaneously with the separation of a new constituent, but it is probable that hardness changes due to other phase separations may occur and not be accompanied by a visible structural change.

On the other hand, Masing[1] observes that in copper alloys containing 3% of beryllium, visible changes in microstructure occur contemporaneously with hardness changes. Corson[2] similarly shows, in regard to copper alloys containing small proportions of nickel silicide, chromium silicide, etc., a phase separation at the same time as hardness changes are occurring. In this case the compounds are retained in solution at high temperatures and rejected at lower.

In the present instance, the extent and speed of the observed changes differ widely in the various alloys examined. On account of the gradual changes which produce hardening, these materials retain their high initial strength for long periods at 800° C. The somewhat narrow range of composition in which the most favourable properties occur appears to be associated with the separation of a special compound or phase.

These phenomena, accompanying creep as indicated in the present paper, are possibly of wider application to other series of alloys. The tendency of a material to harden at the service temperature is probably accelerated by deformation such as is likely to occur in an alloy subjected to high stress in service. The resulting internal movement in the alloy will probably hasten the changes in the material which lead to the hardening action.

[1] G. Masing, *Archiv fur das Eisenhuttenwesen*, 1928, vol. 2, Sept., pp. 185-194.

[2] M. G. Corson, *Proceedings of the American Institute of Metals Division, American Institute of Mining and Metallurgical Engineers*, 1927, pp. 435-450.

The Formation of Ferrite from Austenite.

By Sir H. C. H. CARPENTER, F.R.S., and J. M. ROBERTSON, PH.D., D.Sc.

The present investigation was undertaken in order to discover how the different ferrite-pearlite structures are produced from polyhedral grains of austenite, and how they again revert to austenite during heating. The primary object of the work was to observe how these changes take place, and to find how they are affected by the carbon content, the rate of cooling, the initial temperature, and the time of heating. Consequent upon this it was hoped to formulate a general theory of the structural change. The authors proposed to consider the subject in three parts, and this paper constitutes Part I., which deals with the transformation of ferrite and the distribution of ferrite and pearlite. The variables considered are carbon content and rate of cooling. In the remaining two parts the formation of pearlite and the structural change on heating will be considered. They have studied the formation of ferrite from austenite in a series of three carbon steels cooled at four different rates, and on the basis of the results obtained a theory of the structural change has been put forward. This is designed to explain the effect of carbon content and rate of cooling on (1) the distribution of the centres from which the ferrite crystals grow; (2) the shapes assumed by the crystals during their growth; and (3) the arrangement of the ferrite and pearlite in the final structure. The factors, carbon content, and rate of cooling, exercise their control through their effect on (1) the temperature at which the change begins; (2) the diffusion of carbon in the austenite; (3) the amount of carbon taken up by the ferrite; and (4) the extent to which ferrite crystals coalesce.

The work described includes many types of ferrite-pearlite structures, and provides further information on the origin of (1) the Widmanstätten structure; (2) the banded structure; (3) the sub-boundaries in ferrite; and (4) the cementite boundaries in low-carbon steel.

Refractory Metals for the Induction Furnace.

By J. H. CLUSTERS, B.Sc., PH.D., and W. J. REES, B.Sc.TECH., F.I.C.

The development of electrical methods of metal melting, by induction heating, has raised many difficult problems in the production of durable linings. Apart altogether from refractoriness and chemical durability, the lining must resist the severe strains imposed upon it by the rapid rate of heating and by the steep temperature gradient between the molten metal and the water-cooled coil. Linings are now available which are reasonably durable under normal conditions, and which are unlikely to fail disastrously under brief periods of abnormal treatment such as may occur during a superheat. In this paper the development of these linings and the methods of testing lining materials are described, and possible future developments are discussed.

The authors state that linings of magnesia were used in the original horizontal ring induction furnace. In the coreless furnace fireclay and graphite crucibles have been used, but for the production of steel in quantity durable linings of silica or magnesia, with bonds such as boric acid have been developed. Besides refractoriness, other characteristics required in coreless furnace-lining materials are ability to sinter, corrosion resistance, and low burning shrinkage. Grading is an important factor in the ability to sinter and in the lining material. Microscopic examination of a thin cut through slagged crucibles shows the nature of the slag attack. In comparing the results obtained with different linings, account must be taken of the melting procedure and of the material melted.

The increased life of linings might be obtained from the use of a purer or more refractory material; by improved grading and higher sintering temperature; by a more refractory bond, or the promotion of inter-crystallisation, either directly or by reaction with other materials; or by shaped, tongued, and grooved bricks which could be built into crucible form, and could be patched with cement as wear developed.

The Resistance of Copper-Nickel Steels to Sea Action.

By J. NEWTON FRIEND and W. WEST.

This investigation was undertaken with the object of finding the combined corrosion-resistance effect of nickel and copper when added to ordinary carbon steels. Data is given in this paper on a series of steels with varying percentages of nickel and copper forged and annealed. Specimen bars were exposed to sea action for two years and afterwards scraped clean and examined. In general, the forged alloys suffered slightly greater corrosion than the corresponding annealed bars. The presence of nickel greatly refines the structure of cast steel but there was no evidence that copper does so likewise; the addition of copper, however, up to 3·70% increases the resistance of steel to alternate wet and dry sea action. The most resistant steel of the series contained 1·16% of copper and 3·75% of nickel. It lost least in weight, and its general surface was free from pitting. It is noteworthy that this alloy possessed a fine structure; but resistance to corrosion in these experiments does not altogether coincide with fineness of grain.

X-Ray Investigations of the Crystal Structure of Hardened Steel.

By EINAR OHMAN.

This paper is an addendum to an investigation on the ternary iron-manganese-carbon system, for which the author enjoys a grant from Jernkontoret, and was carried out at the Institute of General and Inorganic Chemistry of Stockholms Högkola under the guidance of Dr. A. Westgren. Part of the work was also done at Metallografiska Institutet, Stockholm. It deals with X-Ray investigations on the crystal structure of hardened steels. These have confirmed the assumption that tetragonal martensite (α^1) is a supersaturated solution of carbon in α-iron. On effective quenching the α^1 phase has the same carbon content as the γ phase from which it was formed.

It is demonstrated that the carbon atoms in the α^1 phase are probably not distributed at random in the interstices between the iron atoms. Simple substitution is also very improbable. The most probable distribution of the carbon atoms is a complex substitution of a group of two carbon atoms for one iron atom.

The decomposition of the α^1 phase on tempering is found to take place continuously with a progressive decrease of the axial ratio.

The causes of the hardness of martensite are discussed and found to be of a very complex nature.

X-Ray Investigation of Certain Nickel Steels of Low Thermal Expansion.

By G. PHRAGMEN.

The low thermal expansion nickel-iron alloys have been studied by means of X-Rays, for which purpose a special camera was constructed to obtain sharp photographs without the necessity of very long exposures. The results indicated that the low thermal dilatation is a property of the face-centred cubic phase when containing about 36% of nickel. This implies that the low dilatation coefficient is not due to a two-phase reaction which compensates the normal dilatation of the two phases. Thus there is scarcely any reason to assume the presence of a body-centred cubic phase in the low expansion alloys. The occurrence of a maximum in the specific volume, taken as a function of the composition, has been verified.

Reviews of Current Literature.

Spectrum Analysis in Mineralogy.

MINERALOGY spectrum analysis was initiated by Hartley in 1884, when he published a paper entitled "Researches on Spectrum Photography in Relation to New Methods of Quantitative Chemical Analysis," which later received much attention from other investigators. Since then much further research work has been accomplished, and analysis by means of the spectrum has gradually become recognised and adopted in mineralogical laboratories as an accessory system of identification of mineral species, and for investigations into their chemical compositions.

Although much progress has been made in its development, there is, apparently, no literature on the subject which conveniently summarises the technique to be employed in mineralogical spectrum analysis, or of the results which the methods have yielded, and Dr. Fitch, having been engaged on this type of work for Messrs. Adam Hilger, Ltd., and being familiar with the literature on the subject, has prepared an informative and interesting review of the work done and the methods employed.

In addition to the analysis of minerals, this review deals with researches on the analysis of rocks and of meteorites, which have been carried out by some workers.

The technique of X-ray spectrum analysis is involved and highly specialised, consequently, in this work, it has only been possible to deal with the subject briefly under five headings, viz :—Methods of excitation of the spectrum ; methods adopted in the preliminary treatment of the mineral, when necessary ; a consideration of the most convenient form of optical apparatus ; the technique involved with the spectroscope and with the spectrograph.

The problem of determining the qualitative analysis of minerals by spectrum analysis, either in testing a mineral for the presence or absence of a particular specified metal, or in examining a mineral to determine all the metals present, are discussed and the procedure adopted in each case is considered. Work on the quantitative analysis of minerals is reviewed, together with analysis of mineral concentrates, rocks, meteorites, mineral waters, and a large number of examples of minerals which have been spectroscopically analysed are given, together with a comprehensive bibliography.

By A. A. Fitch, A.R.C.S., D.I.C., Ph.D., F.G.S., and published by Adam Higler, Ltd., 24, Rochester Place, Camden Road, London, N.W. 1. Price 1/11 post free.

Minerals in Modern Industry.

A STUDY of modern industrial conditions shows how much the material prosperity of a nation is dependent upon its trade in minerals, and it also shows that even the richest of nations in material endowment is not self-contained in its material needs. As a matter of fact, there are no national boundaries in the distribution of mineral supplies ; some kinds are so widely distributed that nearly all countries have adequate supplies within their boundaries ; other minerals, on the other hand, are so distributed that a surplus exists in some parts with a deficiency in others.

Minerals are a fundamental requirement in modern industry, which needs cheap, strong, and mobile power, and the mechanism to employ it. The possession of this power in the form of coal, for instance, is a source of wealth, and when found in proximity to metal-bearing minerals the value is increased because of the functional relationship of minerals to industry. The development of the machine, which is essentially associated with the development of power, is of primary importance in the manufacturing industries, because manufacturing not only enters into the task of preparing in usable form the food and clothing essential to life and modern civilisation, but also engages in the task of making additional comforts and luxuries enjoyed by so many human beings. With the advent of the machine demands on production received a great impetus, and manufacturing equipment has been gradually improved to supply or to anticipate a demand. This increase is reflected in the growing demand for raw materials used in manufacture, such as rubber, timber, paper, and, most important of all, the metals and minerals. The industrial revolution in Great Britain was primarily responsible for the rapid development of mineral resources. This development has now extended to encompass all civilised countries. Commercial facilities are now so widespread and the means of easy and rapid transportation has made such progress, that minerals can be readily exchanged to meet the requirements of any country deficient in an essential mineral.

The subject is discussed very fully in this work, the author presenting the essential economic facts and characteristics relating to the mineral industries. The technical phases of mining, ore dressing, and metallurgy are discussed only to an extent that the author considers essential in understanding the economic aspects of the production of minerals and metals. Mr. Voskuil has concentrated primarily on the economic characteristic of the mineral industry as it affects the United States, and many countries are only referred to briefly, while others are omitted ; but, in the case of those minerals which move extensively in international trade, and in which the United States has a vital interest, world conditions are discussed in a very thorough and informative manner. The international scope of the mineral industry is stressed, also problems associated with international trade in mineral products, and the author points out that the political boundaries of nations, formerly dominated by agricultural considerations, have no natural relation to the distribution of their minerals, which are nevertheless essential for the maintenance of industries in peace time as well as for purposes of defence.

Although this work is primarily a consideration of the mineral industry as it affects the United States the outlook is very comprehensive, and the author discusses the subject in a thought-provoking manner. The book is well produced and complete with a bibliography and convenient index.

By Walter H. Voskuil, Ph.D. Published by Messrs. Chapman and Hall, 11, Henrietta Street, Covent Garden, London, W.C. 2. Price 18s. 6d. net.

Journal of the Institute of Metals.

THE new issue of the *Journal of the Institute of Metals* (Vol. XLIV) is the last to appear in the form that has been familiar to engineers and metallurgists for over 20 years. It contains, as heretofore, original papers and metallurgical abstracts in approximately equal proportions. In future—as explained in an editorial foreword—only papers will appear in the half-yearly volumes, the abstracts being published as a separate volume once a year after being issued monthly to members only. Actually, the new method of issuing the abstracts has been in operation since January, and the monthly parts that have so far appeared have resulted, it is understood, in a remarkable accession of new members anxious to secure the monthly "Metallurgical Abstracts."

The scientific papers appearing in the volume under review are 17 in number, inclusive of the annual autumn lecture by Professor D. Hanson, D.Sc., on "The Use of Non-ferrous Metals in the Aeronautical Industry." The range of subjects dealt with in these important original communications is very wide. It covers such topics as the open-air corrosion of copper, cadmium-zinc alloys, gas removal, and grain refinement, rolled gold and hardness-testing of metals.

The journal is issued in the familiar green cloth binding, is well printed and copiously illustrated. A bulky volume, its metamorphosis into a newer and handier form will be watched with interest by a circle of readers throughout the world—for *J.I.M.* is to be found wherever metals are used.

Edited by G. Shaw Scott, M.Sc., 1930. London : The Institute of Metals, 36, Victoria Street, London, S.W. 1. (Price 31s. 6d. net.)

The New Alloys and—— Machine-tool Design

By Francis W. Shaw, M.I.P.E.

Part V.—Power-actuated Work-holding Devices.

Means for reducing the chucking-fatigue factor are discussed. The principles and construction of mechanical, magnetic, hydraulic, and pneumatic work-holding devices are described and illustrated.

OUR last instalment reviewed the problem of improving hand-actuated chucking devices so as to fit them for the intenser service new cutting materials impose over old. But as long as chucks remain hand-actuated, so long will the fatigue factor be appreciable —nay, will relatively appreciate with every fall in the other time elements, for shortened total-time increases the daily number of chuckings: excellent justification for

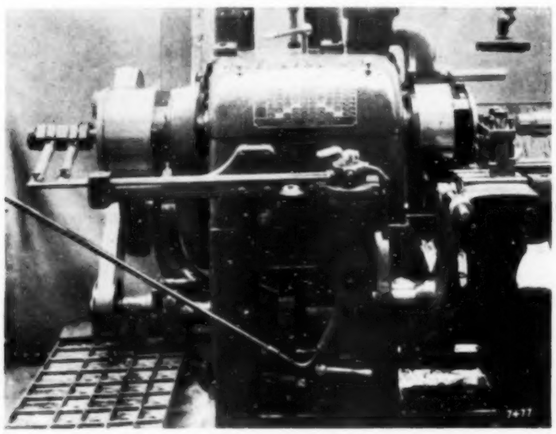


Fig. 27.—Air Chuck and Actuating Mechanism as applied to a Herbert Automatic Chucking Machine.

even involved means for transferring the burden of actuation from the operator to the machine.

By " power-actuated " it is intended to name only those devices in which the actuating medium itself is power-operated; in which the power, in whatever form, is applied in some easy way, as by a light lever, switch, or valve. Thus, in an automatic machine, the work-holding device would not be regarded as power-actuated if a cam or other control element performed the work of chucking, bearing the stresses therefrom, but only if it operated a power-transmitting clutch, an electric switch, or the valve of a hydraulic or pneumatic service.

Four distinct systems of power-actuation have been embodied in chucking devices: (1) mechanical, as by a rotating shaft; (2) magnetic, the device being in effect an electromagnet; (3) hydraulic; (4) pneumatic. None of these can be claimed as new, but the latest of them do something more than merely reduce the effort—chucking is speedier, more certain, and, above all, more elastic— " elastic " in the real sense of the word.

Mechanical Actuation.

We had witnessed, before the high-speed era, many more or less successful and some unsuccessful applications of mechanism to chucks in which the gripping elements, generally collets, were opened and closed while the machine was running. Naturally such mechanism has undergone improvement as duties became more severe, but there is every reason to suppose that the study now being given to means applicable to chucking individual pieces, for which the machine spindle must remain stationary, will ultimately react upon these purely mechanical devices. For two reasons: Since actuation is during rotation, yet must be through some non-rotating member—a lever, say— the mechanism tends to become complicated and it is difficult to avoid excessive friction between the rotating and non-rotating parts; the speed of actuation varies with the spindle speed unless additional complications are introduced.

Even where the spindle can be stationary during chucking, difficulties are not readily overcome, as machine-tool makers have learned by abandoned attempts, though we are aware of one ingeniously simple solution which, so far as we can learn, appears to be an exclusive feature of the Goss and de Leeuw semi-automatic chucking machines (Agents: A. C. Wickman, Ltd.). One would have expected that the first, not the last, thought would have been to turn the chuck-key by power, for that is really in what the invention consists! At the completion of a piece of work the operator merely slides the key, of special form, upon the chuck screw, and depresses a pedal—this operation, through an electric motor, causing the key to turn and open the chuck jaws. Both hands are free to handle the work-piece—an important desideratum when this is heavy. The piece removed, another is inserted, and the jaws closed in upon it by depressing another pedal. It is, of course, necessary to bring the screw into line with the key, and this entails turning the spindle by hand or " inching " it round by power.

Of other means for mechanical actuation we shall not speak, for, in our opinion, better solutions lie elsewhere. Moreover, the trend is in other directions.

Magnetic and Hydraulic Actuation.

Except for light gripping or holding, as in grinding machines, little seems to have been accomplished by

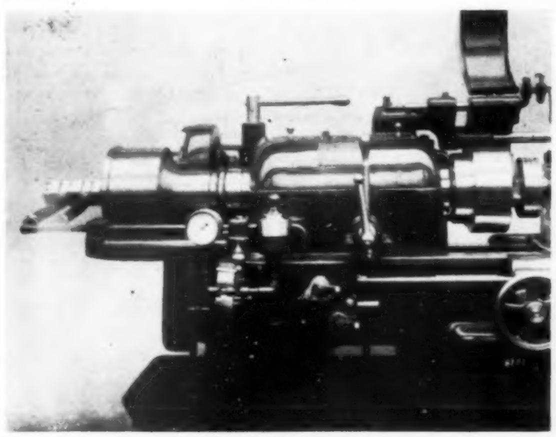


Fig. 28.—Air-Actuated Chuck provided with Pressure Gauge and Reducing Valve enabling the gripping pressure to be regulated.

magnetic media, despite the obvious advantage of being able to draw from a common source energy for chucking and power for driving. An electromagnet would seem ideal as, for instance, for drawing in a bar or tube connected to chuck jaws or collets, and quite as flexible in its

connections as the pipes and valves of hydraulic and pneumatic apparatus; and, it seems to us, far more capable of lending itself to pressure adjustment, for it must be remembered that unless leakage is allowed, the pressure from air or oil or water at the moment when motion ceases is always that of the supply, only controllable if each machine has its own little service plant.

We consider that to apply magnetism directly, as in magnetic chucks, is an ill-advised move for at least two

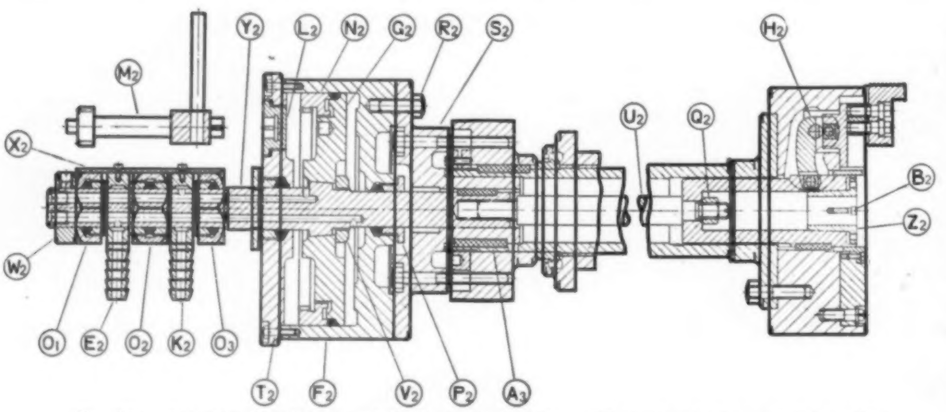


Fig. 26.—Actuating Mechanism of Herbert Air Chuck. Illustrates also the general method of actuating other work-holding devices.

reasons: (1) Because it would restrict the use of the chucks to certain materials; and (2) because the work-piece, if of any of the same materials, would become magnetised, allowing chips to adhere and necessitating demagnetisation. As is well known, a demagnetiser is part of the regular equipment of a grinding department in which magnetic chucks are employed.

Much of that which we have just said applies equally to hydraulic actuation. To us it savours of wasted effort, in a machine provided with hydraulic feed motion, to actuate the work-holding devices pneumatically unless a pneumatic service is part of a works installation. Whilst there may have been a good reason in the particular instance where the Cincinnati Milling Machine Co. have deemed it well to operate a work-holding fixture on their "Hydromatic" milling machine by air, it would seem logical to expect makers of hydraulically driven or fed machines to utilise the same medium for holding the work-pieces.

Here allusion might be made to a scheme of the Gisholt Machine Co. to eliminate the trouble that often arises from uneven work surfaces, and to distribute the total gripping pressure among more points in order to reduce the danger of distorting fragile objects. Projecting from the jaws (of a chuck) are a number of pistons equally spaced. In one example each jaw carries four pistons, the three jaws, therefore, providing twelve equi-spaced gripping points. The pistons communicate to a chamber containing oil. Upon the chucks being operated, several of the pistons make contact with the high spots on the object being gripped, and as further pressure is applied fall back until one by one all the pistons make contact. As the pistons have the same area in fluid contact, the pressure at each piston is the same, and, since the total pressure is borne by twelve pistons instead of by three jaws, the local pressure is but a quarter of that to which the jaws themselves would subject the object at each point of grip. For gripping thin cylindrical pieces, such as ring-gears or tubular pieces, such a device cannot fail to be of service.

A word of warning to would-be imitators. It is a common impression shared, according to their claim, by the makers of these equalising jaws, that oil is incompressible. But it is not. Indeed, it is at least twelve times as compressible as steel, its modulus of compressibility being about 250,000. Thus, a 1-in. square piston, in a 1-in. square cylinder, subjected to a pressure of 1,000 lb., will yield 0·004 in. for every cubic inch of oil behind it; a $\frac{9}{16}$ in. round piston, its area being about $\frac{1}{4}$ sq. in., would yield about 0·016 in. under the same total pressure (1,000 lb.). So, we see, the object is merely held, as it were, by fluid springs, powerful and equally stressed it is true, but, like metal springs, subject to every pressure increment such as that induced by the cutting forces. Since the cutting forces vary in intensity and direction, they must inevitably give rise to impulses in the pistons and, therefore, in the object held by them—impulses varying according to the relationship between the increment forces and the piston pressures. There is, however, a remedy. The jaws themselves should be made the centralising device, the pistons being applied after the work has been centralised.

Pneumatic Actuation.

Whatever the future may tell of magnetic and hydraulic devices, the present trend is towards the employment of air. Over the other media, in the present state of our knowledge, it has very definite advantages and its disadvantages are less pronounced or more readily surmountable.

Many concerns have air-compressing plants installed for other purposes—blowing away the cuttings may be instanced, another time-saving improvement—and some even have air supply to every production department. And the pressure at which the air is normally served usually suits chuck-actuating devices. The cost of a compressor suitable for at least a dozen machines to supply air for chucking and for cleaning runs to about £20 (Messrs. Broom and Wade's estimate). If we add to this the cost of installing the compressor and furnishing the necessary pipe lines, the cost per machine would be negligible compared with the cost of the machine. And

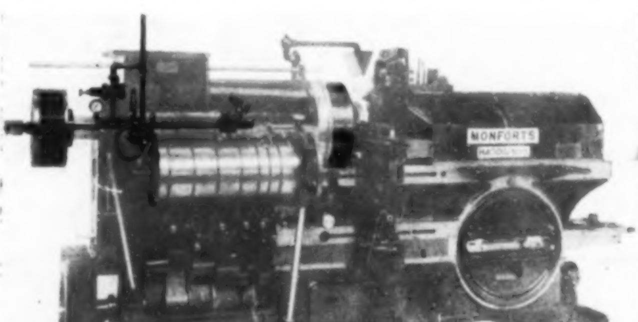


Fig. 29.—Monforts Automatic Chucking Machine, in which the chuck is air-actuated, and in which the gripping pressure is automatically reduced after the roughing cuts so as to free the work-piece from undue distortion for the finishing cuts. (A. C. Wickman, Ltd.)

running cost also is exceedingly low—$1\frac{1}{4}$ h.p. only being required by the compressor.

Air is clean and safe; it is easily regulated; it possesses that quality of "follow-up" so desirable for chuck-actuation; leakages are of little moment. It is not then surprising that designers have turned to it for solution of their chucking problems.

Whilst not forgetting that pneumatic chucking devices

are still in their infancy, we are of the opinion that most of those which have fallen for our study do not exhibit that attention to detail one would expect from machine-tool designers. They show an obvious disregard for mechanical simplicity, compactness, ease of control, and for the wonderful possibilities that exist for regulating the pressure to suit the job. Indeed, much is yet to be done if they are to compare favourably with the other work of the machine-tool maker.

Fig. 30.—Herbert Air Chuck arranged as a Drilling Fixture.

General Principles of Pneumatic Actuation.

A description of the actuating mechanism of the Herbert 9-in. air chuck will serve to illustrate the action of all such mechanism.

As will be seen from the diagram, Fig. 26, air admitted by the hose connection *K2* moves the piston *G2 N2* to the left and through the hose connection *E2* to the right, the rod *U2*, attached to the piston rod *Y2*, moving in the corresponding direction. The duty of this rod is to operate chuck jaws, collets, or other gripping elements, varying with the type of the chuck or work holder. All the mechanism excepting the elements *O1*, *O2*, *O3*, *E1*, *K2*, rotate with the spindle, these elements being restrained from rotation by reason of their connection to the hose. Leakage between rotating and non-rotating elements is prevented by gland-adjustable packings. The method of adjusting the piston against leakage is interesting. A screwed plug *L2*, when removed by the wrench *M2*, whose square end fits a square hole in the plug, admits the opposite end of the wrench, a toothed pinion, into engagement with gear teeth cut within the left-hand portion *N2* of the piston which screws nutwise on the right-hand portion *G2*.

Air admission and release is by two pipes connected to the elements *E2* and *K2* by hose, and a valve to which, in this instance, air is admitted from below, as in Fig. 27, from the air-supply pipe. Operation of the valve, here attached to the headstock, admits air to one side of the piston and at the same time opens a passage from the other side of the piston to the downwardly-bent pipe by which the air is released.

Where it is essential to control the intensity of the grip, means for ascertaining the pressure and regulating it are provided, as in Fig. 28, in the form of a pressure gauge and reducing valve. Regulation is either by hand, as in Fig. 28, or automatic.

It is familiar practice in turning to reduce the grip after the roughing operations of machining in order that the distortion resulting from the heavy grip may not affect the accuracy of the finished work. It is a simple matter to reduce the air pressure in hand-actuated chucks, but not always so simple in automatic machines, if they are to retain full automaticity. Whilst it is possible to arrest the machine after the roughing cuts and then slack off the jaws by hand, this necessitates either the operator's close attention to his job so as to prevent finishing cuts starting before the grip has been eased, or the automatic stopping of the machine at the end of the roughing cuts. If at this moment the operator is attending to another machine, there will inevitably occur a waste of time, adding to that which we are constantly seeking to reduce.

How this problem has been solved—in an exceedingly simple manner—in a Monforts automatic chucking machine, Fig. 29 reveals. The valve of the air chuck (a Forkardt) may be operated either by hand so as to give any predetermined reduced pressure at the completion of the roughing cuts, or automatically by cams attached to the left-hand end of the speed-control drum, as seen in the illustration.

So far we have not witnessed the application of automatic grip-easing devices to fully automatic machines in which individual work-pieces are magazine-fed into the chuck, but clearly some such mechanism as the Monforts just described would solve the problem.

Pneumatic Chucks.

The general construction of the Herbert air chucks Fig. 26 illustrates. The jaws, attached to and adjustable upon serrated slides similar to those of the "Concentric" chuck described in our last instalment, are opened and closed by three levers *H2*, one for each jaw. The levers are oscillated upon their fulcrum pins by a sliding sleeve attached to the rod *U2* by the nut *Q2*. The bush *Z2* supports, centralises, and guides the pilots of tool bars.

One application of the Herbert air chuck to machines other than those of the lathe type is shown by Fig. 30. The air cylinder forms the base of the fixture, here being utilised for holding work-pieces on a drilling machine.

In Fig. 31 the holding device takes the form of a machine vice, the machine being a Herbert horizontal milling

Fig.13 .—Herbert Air-Actuated Machine Vice.

machine fitted with an auxiliary vertical head, two cutters being in action. The vice, of standard type, somewhat modified, its screw having been replaced by what is virtually a piston, is attached to the baseplate carrying the pneumatic apparatus.

(*To be continued.*)

NOTE—Attention is drawn to an error in the caption to Fig. 20, page 210, of the April issue. The wording should be "The Taylor 'Spiral' 4-jaw Chuck," and not "The Taylor 'Spiral' 4-jaw Bar Chuck."—F. W. SHAW.

Stainless Steels.

It has been estimated that the annual loss to the world, due to the corrosion of metals, is more than £500,000,000, but it is not until such figures are put before them that many people realise how important a consideration this wastage is. Not only does it involve expense in repairs or replacement, but it is also responsible for a great many accidents every year. Prevention is better than cure, and engineers have, therefore, been endeavouring for many years to find means to protect steel from corrosion. External devices, such as painting, greasing, or coating with other metals, have all been tried and are still used to some extent, but since the discovery of a means of modifying the internal properties of steel, and the production of stainless steel, these former methods have begun to disappear in many branches of engineering.

The history, composition, and properties of these steels was discussed before the Royal Society of Arts recently by Sir Harold Carpenter, M.A., Ph.D., F.R.S., Professor of Metallurgy at the Imperial College of Science and Technology. The eventual discovery of stainless steel, apparently, was largely an accident. Brearley, to whom the credit for realising the significance of this discovery is due, was not actually investigating corrosion when, in 1913, he found that steels containing high percentages of chromium were very resistant to certain corrosive influences. Tests on such steels had been carried out before this date, notably by Hadfield (1892), Monnarty, and Friend, but little importance had been attached to the results obtained. While Brearley conducted his experiments similar investigations were being carried out in Germany, and in 1913 patents were taken out by Krupps, covering two series of corrosion-resisting steels. These, however, specified a nickel content of from 0·5 to 20%, so the patents did not cover Brearley's steels, which contained no nickel at all. The name "stainless steel" resulted from the first application of these high chromium steels, which was in the manufacture of cutlery, and although it then only referred to its qualities of resistance to vinegar and fruit-juice staining, it now is used to cover resistance to all kinds of chemical attack, including oxidation at high temperatures, solution in acids, and pitting in fresh or salt water.

While various types of stainless steels have been developed, it has been established that the general resistance properties of all increase with the chromium content. Homogeneity is also essential for corrosion resistance. In slow cooled steels the degree of heterogeneity increases with the carbon content; in order to obtain the same resistance properties, the chromium must, therefore, increase with the carbon. But, as a simultaneous increase in the proportions of these two elements leads to the formation of free cementite, stainless steels do not usually contain more than 0·3% of carbon, which is enough to give a completely pearlitic structure with 12% chromium. Steels which are martensitic after quenching or air cooling, are fairly homogeneous, but are also very hard and, although tempering softens them, it reduces their resistance to corrosion. The different varieties of stainless steel can be classified in various ways, but the two chief types are low-carbon stainless steels and cutlery grade stainless steels.

The low-carbon steels are extensively used for purposes where their malleability is advantageous—*e.g.*, in the manufacture of forks and spoons—and for applications requiring corrosion resisting material, having a high tensile strength, and yet tough and capable of machining—*e.g.*, for turbine blades. The production of these steels was only developed a considerable time after medium carbon types had been in use, and it was not until about 1920 that a supply of carbonless ferro-chromium was obtained and their manufacture begun. This type develops its best corrosion-resisting qualities when quenched; and, although it is least immune from corrosion when annealed, its resistance is nevertheless greater than that of steels containing the same amount of chromium and more carbon.

Cutlery grade steels, which contain about 0·3% of carbon, and from 11 to 14% of chromium, are the best known and most used of the stainless steels. They may be hardened in air, oil, or water, but strict precautions should be taken in working, for if they are allowed to cool in air during manufacture cracking may result. The degree of hardness and resistance to corrosion increases with the rate of cooling, but in this, the size and shape of the article must be taken into account, air cooling being used for small sizes and water cooling for the large sizes. Water cooling is liable to produce cracks, and therefore, in the case of intricate-shaped castings, it is better to add about 2% nickel and quench in oil. These steels are used for many purposes besides the manufacture of cutlery. Among the articles which can be and are made from them are:—Surgical instruments, valves for internal combustion engines, pump valves, rams, etc., valves, cocks, and brake rods, and more especially plant for handling chemicals.

There are many modifications of the low-carbon and cutlery grade steels: some are merely experimental, others are produced for special purposes. A recently introduced type of cutlery steel contains about 0·65% carbon and 16·5% chromium; this must be quenched from a very high temperature, thus producing greater hardness than the usual cutlery type possesses. The most interesting alloys contain 18% of chromium. Although insusceptible to heat-treatment, they have exceptional corrosion-resisting qualities, and, therefore, find many applications.

The last part of this paper was devoted to austenitic nickel chromium steels, the properties of which are as follows:—(1) They have a better general resistance to corrosion than any of the other varieties; (2) they can be easily cold worked without their corrosion-resisting properties being destroyed; (3) they have a low yield point, a high maximum strength, remarkable ductility, and resistance to shock; and (4) they have a high resistance to oxidation at elevated temperatures. As Sir Harold Carpenter concluded, it cannot yet be said that there are stainless steels for every conceivable purpose, but, except where cost prohibits their use, materials are available for most ordinary purposes.

Brazing Solder.

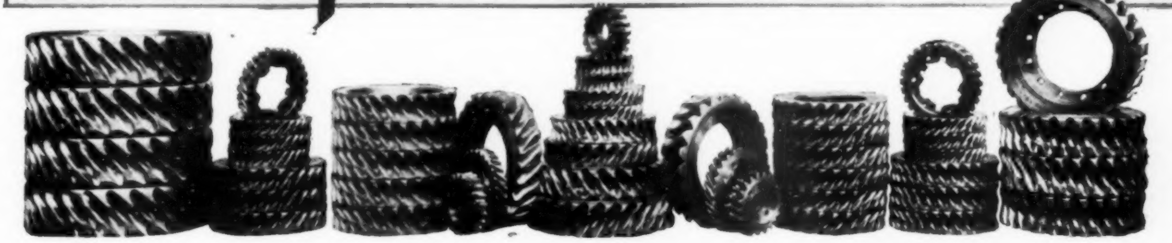
The British Engineering Standards Association has recently published a revised issue of the British Standard Specification No. 263 for Brazing Solder. This new edition has been prepared in order that an additional grade, intended primarily for solder supplied in the form of slittings and wire, might be incorporated. This grade is designated AA, and the three grades now covered by the specification are accordingly A A, A, and B. Another point of difference between the new issue, and the one superseded is that of the dimensions of certain of the sieves for testing granular solder have been modified, so that they might be in exact agreement with the dimensions in the recently published British Standard Specification for Test Sieves referred to on page 33 of this issue of Metallurgia.

Copies of the new Specification (B.S.S. No. 263-1931) can be obtained from the British Engineering Standards Association, Publications Department, 28, Victoria Street, London, S.W. 1, price 2s. 2d. post free.

Crane Construction Transfer.

Messrs. Craven Bros. (Manchester), Ltd., of Reddish, Stockport, have handed over the entire Electrical and Steam Breakdown Crane Section of their business to Messrs. Herbert Morris, Ltd., of Loughborough, who will continue to manufacture "Craven" cranes under the name of "Herbert Morris, Ltd. (Craven Bros. Crane Division)." The transfer includes all patents, patterns and designs connected with the specialised line of cranes developed by Craven Bros., over the past 50 years. Spare parts will be supplied by Messrs. Herbert Morris, Ltd., to the original designs. It is probable that a number of the technical staff of Messrs. Craven Bros. will join the Morris staff. Orders at present on hand will be completed at the Reddish works.

Castings for Bronze Gears



Part IV.

By Francis W. Rowe, B.Sc., M.I.M.M.

Variations in the range of bronze compositions suitable for gears depend upon many factors, and a knowledge of the effect of different constituents is necessary. The author discusses the copper-tin alloys for this purpose.

IN the first article of this series, published in the November, 1930, issue of METALLURGIA, the author indicated the general range of compositions suitable and used for worm gears. Variations in this range depend on the class of gear, the methods used for casting, and the different manufacturer's ideas on the requirements for worm-wheel bronze, and his greater or less knowledge on the effect of various constituents.

The alloys used are all primarily copper-tin alloys, and an understanding of the constitution of this system is therefore necessary.

It is not within the scope of these articles to discuss the constitutional diagram of this very interesting and useful series of alloys in detail, and readers are referred to the now classical researches of Heycock and Neville,[1] and the later modifications to their diagram due to Hoyt,[2] Stockdale,[3] Isihara,[4] and Raper.[5]

Though several of the minor points in the diagram still require further work, the generally accepted constitution of the area of industrial importance is shown in Fig. 21. From this it will be seen that copper is capable of holding up to 16% of tin in solid solution. Thus, all the alloys containing up to 16% tin, when in a condition of stable equilibrium, consist entirely of homogenous crystals of the alpha solid solution. In practice, however, the rate of cooling after casting is never slow enough to allow anything like equilibrium conditions to be attained, so that the actual limit of solubility of tin is usually about 6½%. Thus, in castings only those alloys with less than 6½% tin consist wholly of crystals of a solid solution, and even these crystals are not strictly uniform in composition, being usually strongly cored.

This variation from the normal structure in those alloys of industrial importance—*i.e.*, from 7 to 16% tin—is due to the long freezing range in this region of the diagram. How much the alloy varies from the normal structure depends entirely on the cooling conditions, and these, in turn, are influenced by casting temperature, mould material and mould temperature, and the mass of the casting.

As fairly typical of what occurs in normal sand castings, the diagram in Fig. 22 shows the amount of delta by volume in alloys in full equilibrium, and also the amount of delta occurring in normal foundry conditions. This curve was constructed from the average of many planimetric measurements of alloys of ranging composition, sand cast at a temperature about 60° above the liquidus (corresponding to lowest temperatures usually employed in works practice). The bars were from 1½ in. to 2 in. diameter. With higher casting temperatures (and thus slower cooling), or in larger masses, the amount of delta would be somewhat less, and with casting temperatures nearer the solidus (giving more rapid freezing and cooling), or with chilled castings, the delta would be a little greater in amount.

It will be seen from the curve that the amount of alpha delta eutectoid gradually approaches that indicated by the equilibrium diagram, and from 18% upwards the alloys are in a state of stable equilibrium at room temperatures as far as the proportion of alpha solid solution to delta eutectoid is concerned.

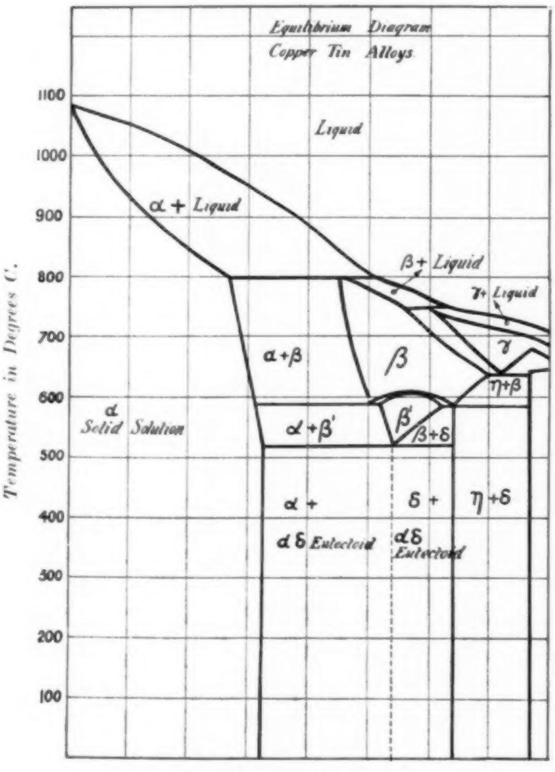


Fig. 21.—Constitution of Copper-tin Alloys up to 40% Tin.

Thus, all the alloys in the commercial range for gears 10—13% show a greater amount of alpha delta than the equilibrium diagram indicates for that composition. This is all to the good for the industrial uses of the alloys, and everything must be done to secure the maximum degree of instability as far as the diagram is concerned when casting, and nothing done afterwards to bring the alloy

[1] *Phil. Trans.*, 1903, vol. 202 A, page 1.
[2] *Jour. Inst. Met.*, 1913, vol. 10, page 238.
[3] *Jour. Inst. Met.*, 1925, vol. 34, page 111.
[4] *Jour. Inst. Metals*, 1924, vol. 31, page 315.
[5] *Jour. Inst. Metals*, 1927, vol. 38, page 217.

any nearer stable equilibrium. The necessity for this will be seen from the following remarks :—

The secret of a bearing metal (for reasons which are not absolutely clear) lies in a duplex structure—*i.e.*, a combination of hard crystals embedded in a relatively soft

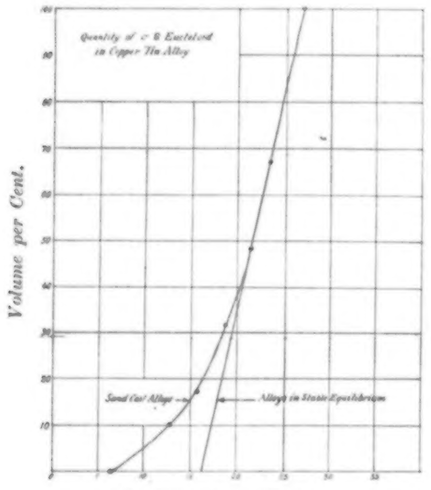


Fig. 22.—Curves showing quantity of Alpha-delta in Sand-cast Alloys and Alloys in stable equilibrium (fully annealed).

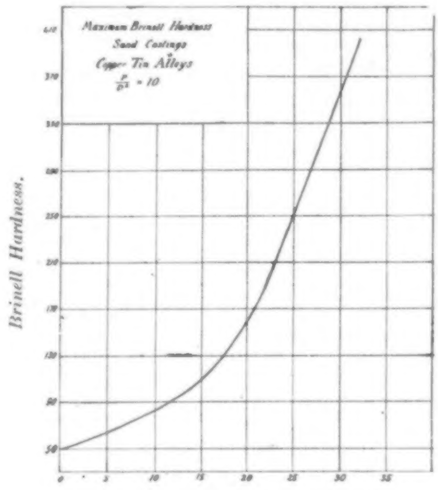


Fig. 23.—Maximum hardness of Sand-cast Copper-tin Alloys. 10 mm. ball, 1,000 kilogs. load.

matrix. It is essential to develop, therefore, to the full this difference.

The saturated alpha solid solution contains 16% of tin, and must obviously be harder than the alpha solution found in commercial bronzes containing 7% tin. Thus, in an $\alpha + \alpha\delta$ structure, there will be a greater difference in hardness if the alpha contains only 7% tin. These features will be appreciated more if reference is made to the relative hardness of the different constituents.

Most of the author's previous work on hardness of various bronzes has been done with a load of 500 kilogs. and a 10 mm. ball. The B.E.S.A. have recently laid down (and rightly so) that the hardness of copper alloys shall be made with a relationship $\frac{P}{D^2} = 10$, which is fulfilled with a 10 mm. ball and a 1,000-kilog. load. There is no definite relationship between Brinell hardness (taken by measuring diameter of impression) taken with a 500-kilog., 1,000-kilog., or 3,000-kilog. load, so that the author has recently taken the opportunity to determine the hardness of the copper-tin alloys with a 10 mm. ball and 1,000-kilog. load. The curve shown in Fig. 23 is plotted from the averages of about 300 determinations on alloys up to 28% tin, and exterpolated up to 32% after determining the equation answering the curve up to 25%. The hardness given represents the maximum value obtainable in sand castings under ideal conditions of feeding—that is, it is the hardness corresponding to the maximum density.

From this curve, taking the metastable alpha as 7%, the hardness is 70. The hardness of the alpha delta eutectoid (27% Sn) is 300, and that of the δ (32–33% Sn) is 400. It should be here pointed out that with a 3,000-kilog. load (such as is normally used for steels) these figures would be materially higher, and for a 500-kilog. load, lower. Under 3,000-kilog. load the hardness of the $\alpha\delta$ would be 400, and delta 550. Thus, in a normal 12% tin bronze we have 9% by volume of $\alpha\delta$ particles of 300 Brinell hardness embedded in an alpha matrix of 70 Brinell, or on the more familiar scale used for steels alpha of 82 Brinell, and alpha delta of 400.

If any annealing is done after casting, or the cooling is sufficiently slow to permit of diffusion and a nearer approach to equilibrium conditions, then not only does some of the δ disappear, but the alpha is hardened.

It has been erroneously stated by one or two people that a low temperature annealing may in certain instances increase the amount of alpha delta. This is definitely wrong. Any heat-treatment which affects the structure at all is bound to lessen the amount of alpha delta and partially destroy the coring.

A fear has also been propounded that very rapid chilling may result in retention of the softer β or β^1 phase. Whilst such conditions might conceivably occur, the author has never met with any cases which would suggest them with even small sections and heavy chills, using anything like a practicable casting temperature to secure maximum density and soundness.

The micro appearance of bronze will be familiar to those even slightly acquainted with the alloy, but one or two typical structures are shown in Figs. 24 and 25. That in Fig. 24 shows a typical patch of $\alpha\delta$ eutectoid in a matrix of alpha solid solution. The internal lakes of alpha surrounded by delta are very clearly seen in the eutectoid shown by this micrograph.

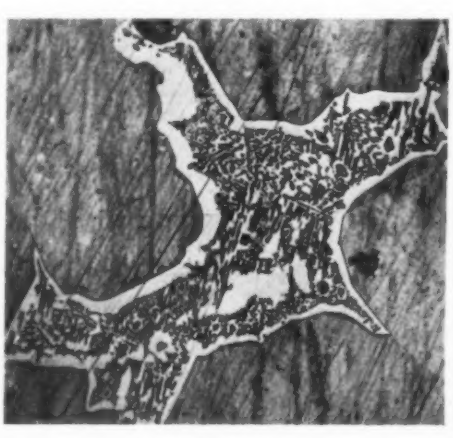


Fig. 24.—Typical patch of Alpha-delta Eutectoid in Ground Mass of Alpha Solid Solution. Magnified 800 diams.

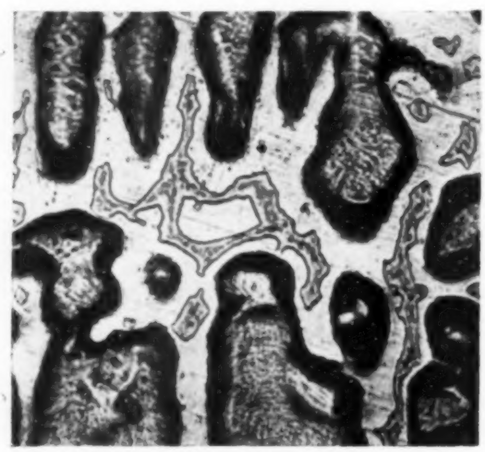


Fig. 25.—Typical structure of Phosphor-bronze, showing "Coring" of the Alpha Solid Solution. Magnified 400 diams.

Fig. 25 shows a typical bronze illustrating the coring. The coring means that the alpha varies in tin content from about 2 to 4% in the centre of the dendrite, where crystallisation first started, to about 10 to 12% where the final solidification of the alpha took place. Only long annealing will cause complete homogeneity of the alpha, and during this process some of the alpha delta would be absorbed.

(To be continued.)

Normalising Steel

By R. Whitfield, M.I.S.Inst.

THE Equilibrium Diagram shown in Fig. 1 forms the basis of all heat treatments, especially of straight carbon steels; there can be included those containing a moderate percentage of some alloying element or elements. The lines indicate the limits of phases where very important changes take place. Owing to the viscosity of the material, however, the changes either lead or lag according to direction, but the lines indicate approximately where the changes are practically complete.

Normal steel, say 0·5%, for example, in a cold state after good rolling will consist of 55% pearlite and 45% ferrite. The pearlite will have a characteristic lamellar structure of plates, alternatively ferrite and cementite, one a comparatively soft substance, and the other intensely hard; these grains of pearlit being surrounded with an envelope of ferrite. If the percentage of carbon is over, say, 1·0% the envelope will be hard cementite; hence, the initial characteristics will be very different. Heating up to and cooling from AI., *i.e.*, about 700° C., will involve no change in the initial structure. But as soon as AI is reached, the components ferrite and cementite begin to mutually dissolve, and the solution is theoretically complete at A32, *i.e.*, about 750° C. By heating a distance above, into the crosslined range marked "Normalising," the solution is complete, and the steel is in an austenitic condition. On cooling again, the reverse action tends to take place but, owing to viscosity, the time rate is extremely important. By varying the rates of cooling from the austenitic phase the state of separation of components can be varied, with important results.

There are several metallurgical states which are recognised, indicating the distance dissolution has taken. These are, taken in order:—Austenite, Martensite, Troostite, Sorbite, and Pearlite. The eutectoid percentage, *i.e.*, about 0·9% carbon, can be called a saturation point, *i.e.*, in very slowly cooled steel the structure would be wholly pearlitic, or be by inference wholly austenitic, martensitic, etc. On the left-hand side of that line there would be the complete separation of the excess ferrite, and on the right-hand side the excess cementite. Let us, however, vary the rates of cooling by quenching in (neglecting the effect of mass, etc.) iced brine, water, oil, molten lead, slowly cooled; then broadly the above structures would occur in the sequence indicated. Thus, a steel would have the characteristics inherent in that structure, all very different, serving valuable purposes. Thus, by suitable heat-treatment, results can be obtained for various purposes. The hardening and tempering of tool steel are only two examples, which need no explaining. These have given rise to investigating more closely the properties of other stages or a happy combination of two of them, each contributing their quota to the demand.

On investigating sorbite, some remarkable properties were discovered, which are being increasingly used in industry. For the want of better terms, sorbitic steel is much tougher and yet even more ductile than well annealed steel; other factors increase its usefulness. A normalised steel is really a sorbitic steel. The mere tenacity of any steel is no criterion of its usefulness, neither is any one physical characteristic and; perhaps the most important characteristics are the ductility and the relative position of the yield point or elastic limit to the ultimate. A comparison of the figures given below will illustrate the importance of normalising.

	Annealed.		Normalised.
Tenacity, tons sq. in.	17.7	......	21.2
Elastic Limit, tons sq. in. ..	11.4	......	16.2
Elongation on 8 in.%..	30.5	......	32.9
Reduction of Area%	38.5	......	43.0
Rockwell Hardness	B33	......	B45

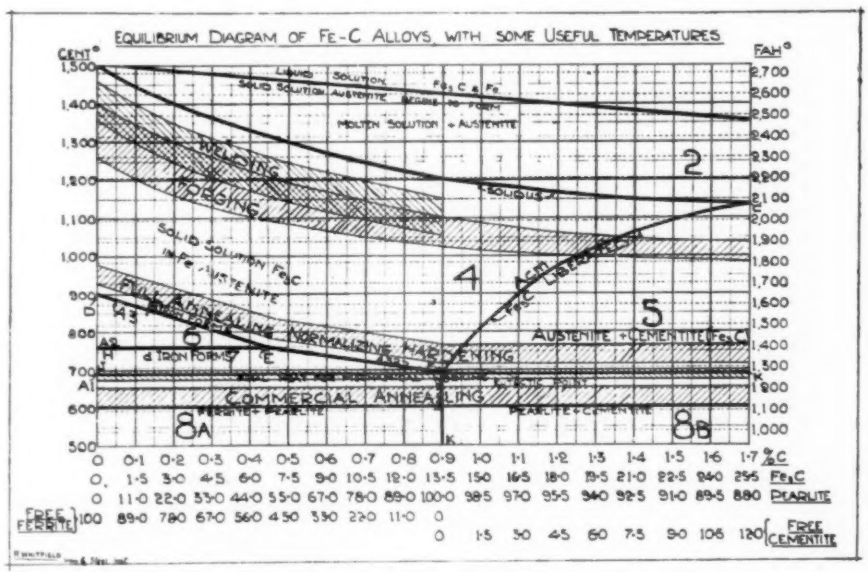


Fig. 1. Equilibrium diagram showing the basis of all heat-treatments of straight carbon steels

The improvement in the tenacity and elastic limit is noticeable, but what are even more important are the marked increases in elongation and reduction of area, yet accompanied by an increase in hardness.

Apart, however, from a physical strength advantage, there are very valuable properties, principally in two directions. When sheets are normalised instead of annealed the facility for drawing is very much enhanced; more difficult and deeper pressings can be produced, and the number of draws necessary can be at least halved; the three draws necessary for annealed sheets can be reduced to one, four to two, five to three, etc., cutting out not only drawing operations, but also immediate annealings, all meaning a considerable reduction in manufacturing costs. In addition to this, much sharper pressings can be made without producing crazed corners common to annealed sheets; this is very important where delicate decoration is to be added.

Similar advantageous properties are available when wire is "patented," the term commonly used. What is really obtained is a sorbitised wire, giving improved strength and drawing powers. Toughening processes, so often exercised on shafts, axles, etc., really mean obtaining a steel having a sorbitic structure. Accompanying these improvements is a much finer grain structure and all that goes with it; a large grain structure always

means brittleness, and the better ductility figures indicate this fine grain structure.

The process of obtaining this structure is as follows :— The steel is heated just above the upper critical range, *i.e.*, into the area marked " normalising " of Fig. 1, soaked a sufficient time—and this is important—for the temperature to penetrate ; the steel is then cooled at such a rate as to ensure the steel reaching the sorbitic stage. This rate must vary considerably with the thickness of articles; thin material can be brought down slowly, thick articles rapidly ; no rule can be given.

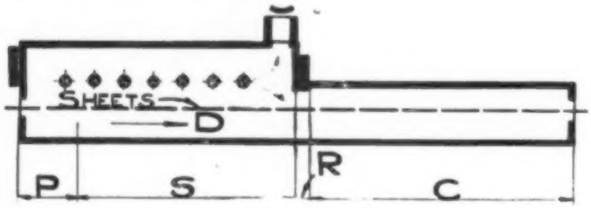


Fig. 2.

An excellent example of normalising is that applicable to sheets, especially for those required for motor-car bodies, where the present artistic designs demand sheets of very deep stamping qualities. The majority of these sheets are normalised in U.S.A. ; but in England, at present, box-annealed sheets form the majority. To get near the desired quality by box anneal demands care and attention, and it can be shown that normalised stock is far superior ; but, while considerable improvements have been made in box-annealed sheets, the full properties of normalised sheets are quite unobtainable by box anneal. The quick cooling necessary is impossible owing to the mass. The box-annealed sheet is definitely pearlitic, and the grain size much greater, with all the accompanying faults ; neither is it easy to obtain the necessary temperature over the critical range without bad oxidation and warping of expensive covers and dishes, which, incidentally, are not used for normalised sheets, hence, this serious item of expenditure is cut out, compensating for the necessary extra cost of a normalising furnace. The maintenance cost of the furnace is much less than that of an equal value of boxes.

An examination of Fig. 2 will illustrate the principles. It is to be realised that this type of furnace is not confined to normalising only; it can be used for annealing or hardening. Preheating, soaking and cooling can be dealt with individually. Not much has been said about strain in sheets. Generally, as these come from hot mill, strains are heavy, and must be removed. Box anneal will eliminate these by the use of a long soak. To properly normalise sheets, however, not only must the strains be removed, but the grain size reconstructed, and a definite rate of cooling is necessary. Incidentally, much wider sheets are dealt with in normalising furnaces than in a box furnace. Furnaces up to 90 in. wide dealing with sheets 80 in. in width are easily dealt with ; whereas 48 in. is an exceptional width for box anneal, and uniformity of temperature is practically impossible.

The sheets, or packs of three to five, according to thickness, are placed upon the charge table and are forwarded into the preheating zone P, where the rate of preheating is rapid, owing to difference in temperature ; but slowing up as the temperature difference is reduced ; this corrects the distorted grains and starts to relieve the strains. This process continues through the soaking zones and by the time the sheet approaches R, its temperature is above the upper critical range, and the sheet is, therefore, in an austenitic state, the previous grain size is completely eliminated, and all strain has disappeared. The hot products of combustion from the burners, ranging along each side of the soaking zone, can take two paths, each controllable. Near R, a door controlling the entrance to the cooling chamber C, is a short stack resting on the heating chamber. This is also controllable. By varying either or both the flow of hot gases can be controlled. If the door is close to the passing sheets, the majority of hot gases pass up the stack, and the small remainder pass into the cooling chamber; so that, while the sheets are adequately protected from oxidation, the rate of cooling is fast. If, on the other hand, the stack is closed and the door fully open, all the waste gases pass into the cooling chamber, and the rate of cooling is at a minimum. The sheets are then really subject to a slow anneal. This enables the sheets to be heat-treated within wide limits, and strictly controlled, especially if a temperature control is used, which is very important for mass production.

When the masses are large, such as axles and shafts, they are heated in a bogie furnace, and then drawn into the atmosphere. But this method produces variable results, owing to the different states of atmosphere, and especially if the masses vary.

In conclusion, the properties of sorbitic steel are well worth studying, and an examination of the diagram will reveal many possibilities in various directions. It is the only true scientific basis to work from. Furnace builders have paid an increasing attention to scientific facts, and many mass production and other furnaces are carefully designed to give the scientific conditions laid down by the manufacturer. Attention to the above facts, coupled with the scientific and economic combustion of fuel, makes the furnace designers' work complicated, but they have risen nobly to their task, and are worthy of every consideration. The rule of thumb has passed, and so it must in many other directions, if the good old reputation of this country is to be maintained.

Catalogues and Other Publications.

The reliability of Nickel Alloy Steels has brought about a considerable expansion in their use for products requiring great strength together with minimum size. All types of gears may be classed among such products, and the extensive use of nickel steels in their manufacture is admirably described in an article in the April *Nickel Bulletin*. This article, which contains a number of interesting illustrations describes the plant, methods and products of the Moss Gear Company, Aston, Birmingham. Spur, worm, spiral bevel and double helical gears, rear axles, and gear boxes, geared transmission units and camshafts, are all dealt with, whilst a large proportion of the space is devoted to the heat-treating equipment used. Other articles in the Bulletin include those on " Nickel Cast Iron in ' Fielding ' Engines," and " Nickel-Chromium Steels in ' Vulcan ' Locomotives."

Those who are familiar with welding in any one of its forms will be aware that its successful application depends very much upon the skill and experience of the operator, and that, therefore, unless provision is made for instructing operators in welding, progress in that industry will be restricted. The April issue of the *Welder* will, therefore, be of considerable interest and value to many, for it contains a supplement entirely devoted to the Training of Welders.

We have received a number of bulletins dealing with tungsten carbide from Messrs. Burton, Griffiths and Co., Ltd. They form part of a series on the subject and have been prepared by Mr. Frank Curtis for Messrs. Kearney and Frecker of Milwaukie, Wis., U.S.A. Much useful information is given in connection with this cutting material, particularly with its use on milling machines. The assertion is made in one of the bulletins that tungsten carbide has obsoleted thousands of machines in the same way that other developments have done in the past. The only difference is that the blow is more severe this time. The requirements of tungsten carbide are too drastic to permit a half-way compromise. It is a case of getting up enough courage to discard the old."

Rapid progress has undoubtedly been made in the development of machine-tools during the past decade, and greater rigidity as well as increased speed has become a necessity to obtain the best result from improved cutting materials now available. Those interested in tungsten carbide should have this series of bulletins as they are both interesting and informative. Readers who desire them should apply to Messrs. Burton, Griffiths and Co., Ltd., Sparkbrook, Birmingham.

Recent Developments in Tools and Equipment.

THE BECKER COKE OVEN.

THE attention of our readers was drawn, in our February issue, to an order which had been placed with the Woodall-Duckham Co., of London, for a coke-oven installation. As previously stated, the contract comprises a battery of 51 ovens, capable of producing 5,000 tons of coke per week; the necessary coal-washing, blending, crushing, and handling; coke-screening and handling; tar and ammonia recovery and benzol recovery and rectification plant are also included. This contract, we understand, was awarded to the above company by the Lancashire Steel Corporation, and is in connection with the reconstruction of their Irlam works.

The ovens will be of the Becker regenerative type, and will be so constructed as to permit of under-firing by means of blast-furnace gas, producer, or coke-oven gas, as required. This type of oven has received considerable attention among coke-oven engineers during the past few years, during which time orders have been placed in this country for installations by the following companies:—

Company.	Location of Plant.	No. of Ovens.	Capacity in Tons Coal per Day.
Nunnery Coke and Gas Co., Ltd.	Handsworth, Sheffield	25	520
Thorncliffe Coal Distillation, Ltd.	Smithywood, Sheffield......	59	1,200
British Benzol and Coal Distillation, Ltd.	Bedwas, South Wales	35	660
J. Lysaght, Ltd.	Scunthorpe, Lincs...........	47	1,000
South African Iron and Steel Industrial Corporation	Pretoria, South Africa	—	750
Lancashire Steel Corporation, Ltd.	Irlam, near Manchester.....	51	1,046

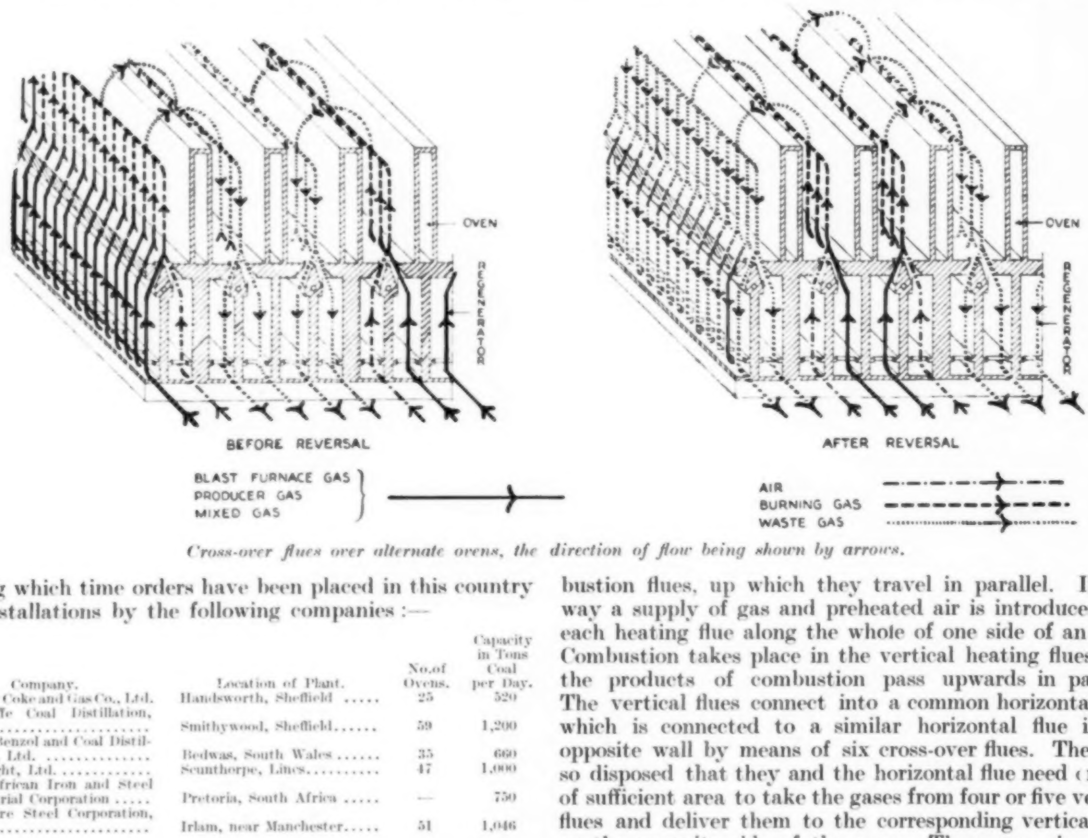
In addition to these orders for Becker ovens placed with the Woodall-Duckham Co., the remarkable development of this type of oven is evidenced by the fact that since its inception in 1922 orders have been placed throughout the world for more than 5,800 ovens, with a yearly carbonising capacity of approximately 45,000,000 tons of coal. In view of this remarkable development, a brief reference to the distinctive features of this type of coke oven and the claims made by its designers may be of interest.

The Becker oven has been designed to meet the demand for an oven capable of being heated uniformly at all parts, irrespective of length and height, and have a minimum coking time consistent with its particular width. Such an oven will give a maximum output for any defined dimensions, and produce a coke of uniform quality.

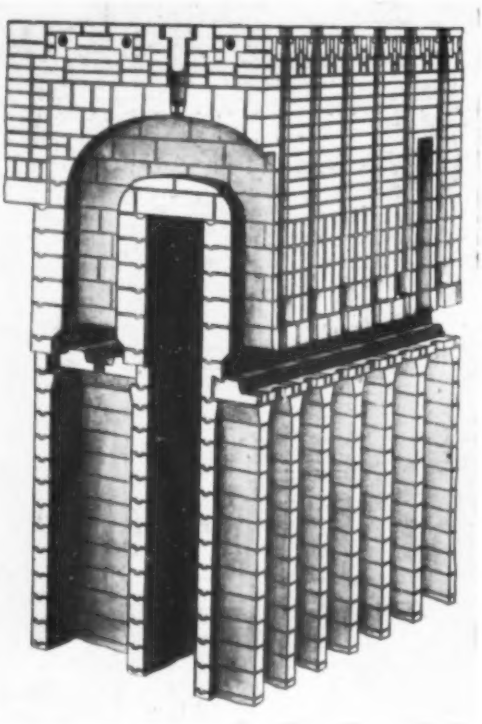
The basic feature of the Becker oven is the cross-over flues. In ovens of large capacity this arrangement makes it possible to employ horizontal flues of small dimensions, in spite of the big volume of gases to be handled, thus ensuring great strength of battery structure, even heat distribution at every point on the oven wall, and high thermal efficiency.

The oven is of the regenerative type, in which the vertical heating flues along each side of each oven are connected to regenerators; two regenerators being built under each series of vertical flues. When employing blast-furnace or producer gas as the heating medium, air travels up one regenerator and gas up the other. Ascending through the regenerator the air reaches the base of the vertical heating flues. At the same time gas ascends the other regenerator, meeting the air at the base of the combustion flues, up which they travel in parallel. In this way a supply of gas and preheated air is introduced into each heating flue along the whole of one side of an oven. Combustion takes place in the vertical heating flues, and the products of combustion pass upwards in parallel. The vertical flues connect into a common horizontal flue, which is connected to a similar horizontal flue in the opposite wall by means of six cross-over flues. These are so disposed that they and the horizontal flue need only be of sufficient area to take the gases from four or five vertical flues and deliver them to the corresponding vertical flues on the opposite side of the oven. There are six cross-over flues to each *alternate* oven. The intermediate ovens have no cross-over flues. From the vertical flues the waste gases are equally distributed in the two regenerators below, whence they pass finally to the waste-gas flues on both sides of the battery. After the gases have been allowed to flow in one direction for a period of approximately 20 minutes, they are made to flow in the opposite direction.

This arrangement of heating ensures that the travel of gases is short and the speed slow, so that an excellent regulation can be obtained with a low-pressure differential. The system gives that graduation of temperature which enables all parts of the charge to be completely carbonised at the same time, and this requirement is obtained without the elaborate distribution of dampers.



Cross-over flues over alternate ovens, the direction of flow being shown by arrows.



A section showing one of the Cross-over flues.

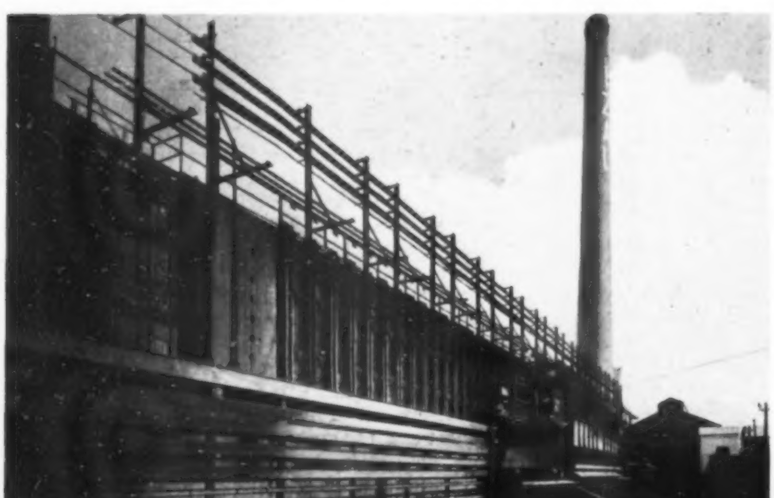
The heating gases in all the vertical flues on one side of the oven always travel in parallel flow, and the rate at which combustion takes place in these flues is controlled from top to bottom, giving uniform heating. The horizontal flues, being shallow, prevent interference with the heat penetration at the top of the charge. With this simple system of heating in parallel there is no possibility of short circuiting and consequent loss of efficiency.

In addition, the arrangements for changing the heating medium give this type of oven great flexibility, as it is readily changed over, either partially or wholly, from coke-oven gas to producer- or blast-furnace gas.

Modern improvements as regards capacity, output, etc., are, however, of little value unless the oven will stand up to hard work year in and year out, without leakage or failure. In strength of construction the Becker ovens show many important advantages. The oven itself is supported direct from the foundations by a solid wall of brickwork. The divisions between the vertical flues give support to the walls at short intervals. The two regenerators under each series of vertical flues, are separated by a wall, which gives additional support to the upper structure. This arrangement enables the oven to be heated by coke-oven gas, producer-gas, or blast-furnace gas.

The simplicity of the heating arrangements, and particularly the absence of any large dimensional flues, make the Becker oven a strong oven, and its designers claim that it fulfils all the requirements of modern coking practice.

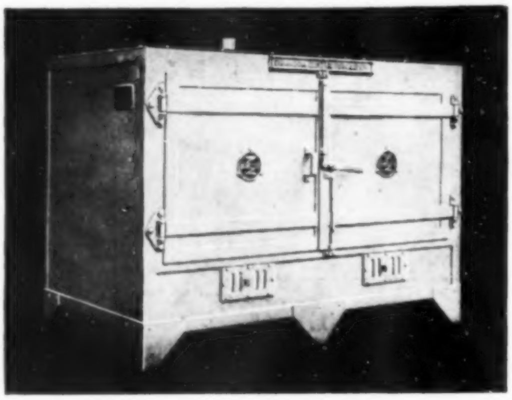
Coke side of Becker installation at Thorncliffe Coal Distillation Ltd.



INDUSTRIAL ELECTRIC OVENS.

The Birmingham Electric Furnaces, Ltd., have recently designed a new type of electric oven for industrial drying, baking and low-temperature heat-treatment processes at temperatures up to 350° C. It has been standardised in four sizes, the smallest of these having internal dimensions of 1 ft. 6 in. × 1 ft. 3 in. × 1 ft. 6 in., while the largest is 3 ft. × 5 ft. × 5 ft. The oven body is of the double-cased form of construction, retaining heat insulating material between inner and outer sheet steel casings. Insulated doors are fitted. The smaller sizes have single, and the larger double-swing doors. The effective manner in which the walls and door are insulated gives the oven a high thermal efficiency when in operation. Guides are fitted in the oven for shelves or rods to support the work. Arrangements are made for the removal of fumes given off in certain processes.

The heating elements are self-contained units which can be readily inspected or replaced when necessary. They



consist of nickel-chromium ribbon wound on porcelain insulators, and ample protection is provided by means of a screen. The heating elements are distributed uniformly over the hearth, the heat rising upwards by natural convection, giving regular and uniform heating.

Many of the purposes for which this oven is eminently suited necessitate close control of temperature. To secure the best results, all these ovens are fitted with automatic temperature control gear by means of which a desired temperature can be maintained without attention from the operator. All live parts are protected against contact with the charge, and a switch is fitted which automatically de-energises the heat-elements when the door is open.

The oven is built as a complete unit, with the switch gear and temperature controller mounted on the side, requiring only a connection to the power supply. It can, therefore, be placed in

the line of flow of the work, and owing to its portability, easily moved if necessary. Although, as previously stated, these ovens are supplied in certain standard sizes, which gives more favourable conditions in regard to price and delivery, other sizes and specially designed equipment, such as vertical or horizontal conveyor ovens, truck loaded ovens, etc., for enamel stoving, core-drying, and other processes, are constructed. Such ovens are usually equipped with forced air circulating system, designed to provide either direct re-circulation of the air in the oven, or re-circulation of part and exhaustion of the remainder to atmosphere. The latter system is necessary if inflammable fumes are evolved by the charge.

SPECIFICATION FOR TEST SIEVES.

THE British Engineering Standards Association have just issued a standard specification for test sieves. In its preparation the Committee have had before them the standard sieves of the Institution of Mining and Metallurgy, together with the standard sieves series of the U.S. Bureau of Standards. Particulars of these sieves are given in an appendix to the specification.

It has been considered advisable to divide the British Standard Test Sieves into three series :—

1. Fine-mesh sieves made of woven wire cloth with a size of aperture ranging from 0·0021 in. (300 mesh) to 0·1320 in. (5 mesh).

2. Medium-mesh sieves made from woven wire cloth with a size of aperture ranging from $\frac{1}{32}$ in. to $\frac{1}{4}$ in.

3. Coarse-mesh sieves made from perforated metal plate with a size of aperture ranging from $\frac{1}{4}$ in. to 2 in.

The series of fine-mesh sieves has a screening area varying from 35 to 44%, and is based on a ratio of the fourth root of two between linear aperture measurements of consecutive sieves ; whilst in the other two series the increments in size of aperture are simple fractions of an inch.

Any individual user of the Standard Test Sieves would not, of course, use the whole range of sieves, and the sizes of apertures of the fine-mesh sieves are so arranged that they may be readily grouped into four complete series, as follows :—

Approximate Size of Aperture in Fractions of an Inch.

$\frac{1}{480}$	$\frac{1}{400}$	$\frac{1}{333}$	$\frac{1}{288}$
$\frac{1}{240}$	$\frac{1}{200}$	$\frac{1}{168}$	$\frac{1}{144}$
$\frac{1}{120}$	$\frac{1}{100}$	$\frac{1}{84}$	$\frac{1}{72}$
$\frac{1}{60}$	$\frac{1}{50}$	$\frac{1}{42}$	$\frac{1}{36}$
$\frac{1}{30}$	$\frac{1}{25}$	$\frac{1}{21}$	$\frac{1}{18}$
$\frac{1}{15}$	$\frac{1}{12}$	$\frac{1}{10}$	$\frac{1}{9}$

It will be noted that in each group the sieves are so graded that the size of aperture of each sieve is approximately double that of the sieve below it.

In order to simplify manufacture and thus reduce the cost of production, the Committee have considered it necessary to adopt mesh numbers commonly used, and to specify sizes of wire included in the Standard Wire Gauge Series, or intermediate sizes which are in common use. These restrictions have necessarily limited the choice of aperture dimensions, and rendered the progression of the series of fine-mesh sieves slightly less uniform than could have been secured if odd counts and wire sizes had been adopted.

The size of the apertures being the most important feature of the cloth, special care should be taken that it deviates to a minimum degree from the nominal dimensions specified in Tables, I., II., and III.

It is fully realised that the figures given in the specification for tolerance on occasional large apertures are very wide, but it has been found impracticable, in the absence of any reliable data on the subject, to specify closer limits at the present time. They must be regarded as tentative only ; the Association trusts that it may have the co-operation of both manufacturers and users in this matter, so that revision of the specification in the direction of greater accuracy and uniformity of aperture size may be possible after one or two years' experience has been gained. Any information as to rapid methods of measuring the aperture size of woven wire cloth, and as to results obtained upon material supplied under this specification, should be sent to the offices of the Association.

The many uses to which test sieves are put are so varied that the Committee are unable to specify the material from which they are to be made. For ordinary purposes, though, it is recommended that steel should be used for sizes coarser than 40 mesh, and phosphor bronze for the finer meshes.

Copies of the new specification (B.S.S. No. 410—1931) can be obtained from the British Engineering Standards Association, Publications Department, 28, Victoria Street, London, S.W. 1, price 2s. 2d. post free.

BRITISH CHEMICAL STANDARDS.

Pure Standardised Reagents and Metals for Volumetric Analysis.

IN addition to the standardised analysed samples of steels, irons, ores, and non-ferrous alloys, which this organisation has prepared from time to time since 1916, a need has been felt for certain standard reagents and metals of the highest grade of purity—similar to those issued by the U.S. Bureau of Standards—for volumetric analysis, calorimetry, and pyrometry.

The classifying of reagents as "chemically pure" has but little meaning, and gives chemists no precise information as to the extent or nature of the impurities which may be present. The "A.R." classification is a step in the right direction, and indicates many of the limits of impurities which may be expected ; but whilst this is a considerable help, it is felt that for a few special standardising purposes many chemists would like to be able to obtain from a reliable and impartial source supplies of certain high-grade reagents and metals with a definite guarantee as to their purity, and a definite statement of the amount of the impurities they contain.

British Chemical Standards Headquarters are therefore attempting to meet this requirement, and the following table shows at a glance what substances are now available:—

Material.	Purity %	M.P. °C.	Calorific Value.	Chief Uses.
Benzoic acid	99·9	—	6325	Calorimetry and standardisation of volumetric solutions of NaOH, etc.
Sodium oxalate	99·94	—	—	Standardisation of N/10, etc., potassium permanganate.
Tin................	99·98	232	—	Calibrating pyrometers and volumetric analysis.
Lead	99·98	327	—	Calibrating pyrometers, assaying, and volumetric analysis.
Zinc	99·95	419	—	Calibrating pyrometers, vol., volumetric analysis, and assaying tests.
Aluminium	99·82	658	—	Calibrating pyrometers
Sodium chloride	99·96	801	—	Calibrating pyrometers and volumetric analysis
Copper	99·91	1083	—	Calibrating pyrometers and volumetric analysis

Each sample is issued with a certificate showing the complete analysis, together with the calorific value, or exact melting point, according to the purpose for which the material is intended, also working details for its use.

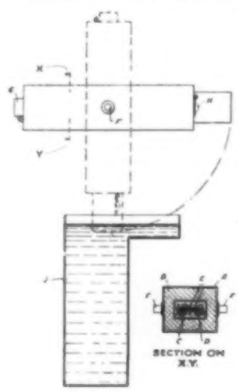
As an example, the B.C.S. benzoic acid makes an excellent standard not only for calibrating the Mahler bomb-type of calorimeter, but also the sodium peroxide type of calorimeter, such as Roland Wild's. The same reagent may be used to advantage as a primary standard for alkalimetry—a use which is not yet sufficiently appreciated in Great Britain.

The price of the samples are quite modest, ranging from 7s. 6d. to 10s. 6d. each ; and anyone who is sufficiently interested should send to the headquarters of the movement, 3, Wilson Street, Middlesbrough, for a free descriptive leaflet.

Some Recent Inventions.

TILTING HEAT-TREATMENT FURNACE.

A furnace for the heat-treatment of parts, recently designed, allows the furnace body to be rotated from a horizontal charging position to a vertical position for discharging. The object of this design is to provide a rapid and convenient means of charging and discharging, especially where the objects treated require to be quenched immediately on being taken out of the furnace. For this purpose the furnace body is supported on trunnions, above the floor level, in such a way that it can be readily tilted to a vertical plane. This furnace, which is preferably of the electric resistor type, but may be of the types heated by eddy currents, by gas or by oil, consists of an outer shell, with a door at one or both ends. Inside this shell a refractory heat-insulating lining is placed, and the chamber of the furnace is lined with nickel-chromium or other heat-resisting metal sheet. For certain types of straight work, such as tubes, bars, twist drills, etc., where distortion must be prevented, the metal lining is omitted, and the articles are inserted in tubes of nickel-chromium or other suitable heat-resisting material laid in the furnace chamber.



The accompanying illustrations show an example of a furnace of this design adapted more particularly for treating tubes, bars, drills, steel shafts, and work of a similar type. The furnace is a relatively narrow chamber C of firebrick B, contained in a metal shell A, having inserted tubes D of nickel-chrome, in which the articles to be treated are inserted. The furnace body is provided at the charging end with a pivoted door G, and a similar door H at the other end. The furnace, which is heated by resistor coils E, can be swung about the trunnions F, from the horizontal position to a vertical position, as indicated. In the latter position an extension of the furnace body is immersed below the surface of the oil or other quenching liquid in the tank J. When in this position the door H is opened by a lever arrangement, and the articles discharged into the tank without contact with the atmospheric air.

343,306. The Electric Furnace Co., Ltd., and D. F. Campbell, both of 17, Victoria Street, London, S.W. 1, Patentees. Messrs. Abel and Imray, Agents, 30, Southampton Buildings, London, W.C. 2.

ACID-PROOF ALLOYS.

Alloys of iron and silicon, in which the silicon contents vary between 7 and 20% offer considerable resistance against the effects of acids and other corrosive media. When the silicon contents lie between 7 and 12 % these alloys have considerable strength, but their resistance to acids is smaller than that of alloys with a higher silicon content. With an increase in silicon contents, however, the strength of the alloys is materially reduced, and above 16% silicon the alloys are brite.

It is claimed that acid-proof alloys can be obtained by alloying titanium in certain proportions with the usual silicon-containing and acid-proof alloys, or by partly replacing the silicon by titanium. A substantial improvement both in the mechanical and in the casting properties as compared with the usual acid-proof alloys is especially obtained with the group of alloys in which titanium partly replaces the silicon, for example, with alloys which contain from 0.2 to 10% of titanium, and up to about 20% of silicon, and particularly with alloys containing from 2 to 4% of titanium and 16% of silicon. Alloys of this composition are distinguished by their complete homogeneity, and are free from gases and impurities. It is to be emphasised that no remelting is necessary in their production, and that on the first melting down a material is obtained of uniform, fine-grained structure without oxidic or other admixtures (for example, Al_2O_3, SiO_2, and the like), and possessing an increased resistance to corrosion, an increased tenacity, and definitely decreased brittleness. Further, the suitability for casting of these alloys is improved by the influence of the titanium. The titanium effects an increase of the number of the crystal centres, prevents the formation of trans-crystallization zones, and diminishes the tendency to form cracks in the castings.

343,003. A limited company, formerly the Skoda Works, Plzen, Czechoslovakia, patentees. Messrs. Reddie and Grose, agents, 6, Bream's Buildings, London, E.C. 4.

WELDING ALUMINIUM OR ITS ALLOYS WITH OTHER METALS.

Definite temperatures and pressures have previously been necessary to cause aluminium and aluminium alloys to combine with other metals. Under manufacturing conditions it has been difficult to avoid small variations in practice, and these have an unfavourable influence on the quality of the products, and tend to increase costs. Investigation of the combination process apparently shows that most of the failures are due to insufficient pressure. The aluminium or aluminium alloy is so elastic at the welding temperature that the pressure necessary for an intimate combination cannot be exerted on the combining surfaces, but is made inoperative owing to previous alteration in shape taking place.

A new process has been devised with the object of overcoming these difficulties. For this purpose a separate thin intermediate layer of aluminium or aluminium alloy is first welded to the base metal. This may be called the intermediate welding layer. The piece of aluminium or aluminium alloy of the requisite thickness is then welded on to the intermediate layer without difficulty.

The process may comprise a low temperature aluminium for the intermediate welding layer, as, for example, an alloy consisting of 80% aluminium, 1% bismuth, 2% tin, 12% zinc, and 5% cadmium ; or an alloy consisting of 90% aluminium, 2.5% bismuth, 2.5% tin, and 5% cadmium. With these alloys the welding of the intermediate layers may be effected at a temperature of about 340° C. In this way it is possible to weld together thick pieces of aluminium or its alloys and other metals in one working operation.

343,156. A. R. Hetzel and J. M. Hetzel, of Nurnberg, Germany, patentees. Messrs. Haseltine, Lake and Co., Southampton Buildings, London.

IMPROVEMENTS IN NON-FERROUS ALLOYS.

Non-ferrous alloys used in the manufacture of tubes for special classes of work are required to be non-corrodible. Especially is this so in the manufacture of condenser tubes, locomotive boiler tubes, tubes for heating and cooling water, and tubes for sugar, salt, and other evaporators. A recent development in non-ferrous alloy production for this purpose consists of copper, nickel, and chromium. The object is the production of a non-corrodible alloy of great tensile strength, capable of being readily rolled, drawn, extruded or worked, and of great value for being worked into various kinds of tubes, particularly those to which reference has been made. The composition of this improved alloy is based on a 70-30 copper-nickel alloy with the substitution of chromium up to 4% for a corresponding percentage of eithre copper or nickel. Impurities have a deleterious effect on the resultant alloy ; it is therefore advisable that the metals used should be of a high percentage of purity. In practice it has been found that the following approximate composition is suitable for the purposes mentioned—*viz.*, electrolytic copper 67.5%, nickel 30% and chromium 2.5%.

338,676. G. W. Whiteman and Imperial Chemical Industries Ltd., patentees. A. Millward Flack, agent, Imperial Buildings, London E.C. 4.

Business Notes and News

Iron and Steel Reorganisation.

During a visit to her constituency at Middlesbrough recently, Miss Ellen Wilkinson, M.P., announced that a meeting of the British Iron and Steel Federation would probably be held in Middlesbrough on May 17, the object being to discuss the proposals of the Government for the reorganisation of the iron and steel industry, the position of which is becoming increasingly serious. A great deal of voluntary reorganisation has been carried out in some districts, but financial difficulties are holding up further progress. Details of a scheme, which includes the granting of a moratorium by debenture holders and creditors, and the provision of fresh capital to enable Pease and Partners, Ltd., to tide over the trade depression, have been issued by the Advisory Committee appointed in last October. It has been realised that the whole financial structure of the company will have to be reorganised, but the Committee do not intend to embark upon that work yet, as plans are being considered for closer working and amalgamation in the iron and steel industries, which may put an entirely new light on the matter. There is a belief in some quarters that the Government is considering a scheme for compulsory amalgamation of iron and steel companies in certain areas, and though the real nature of these plans has not been announced, it is quite likely that this area grouping will form part of the scheme.

The Cracking of Boiler Plates.

In a paper delivered at the Annual meeting of the Iron and Steel Institute in London, Dr. W. Rosenhain and Mr. A. J. Murphy described the results of an investigation undertaken in the metallurgical department of the National Physical Laboratory, at Teddington, on the causes of cracking of boiler plates. This investigation took the form of endurance tests of certain samples under exposure to mildly corrosive liquids. Bending tests were carried out every 24 hours, and the test pieces were continuously immersed in the various liquid media. A feature of the results obtained was that the influence of tap-water was considerably greater than that of less mildly corrosive agents, such as air or even caustic-soda solution.

Steelworks Closed Down.

That the demand for steel rails, either at home or for overseas, is at present very poor, is emphasised by the fact that the Barrow Hematite Steel Co., Ltd., have recently closed down their steelworks at Barrow, owing to lack of orders. Contracts in hand have been completed, but there has been no prospect of new steel rail orders to keep the plant going. The company's hoop works, however, will remain in operation, as will also their two furnaces used for making iron.

Quality of British Springs.

Following a suggestion to the Springs Research Committee of the Department of Scientific and Industrial Research, that certain foreign vehicle springs were superior to those produced in this country, a supply of foreign springs was obtained and put through a series of tests at the National Physical Laboratory. It was found that they were made of chrome-vanadium steel of about the same composition and hardness as British chrome-vanadium springs, but endurance tests in the laboratory and under road-running conditions showed them to be slightly stiffer than the British springs. Surface weakness was very marked, and after extensive tests it was established that the British chrome-vanadium steel springs were at least 30% stronger than those from abroad.

Technical Agreement between British and Russian Firms.

A technical agreement of considerable importance has been signed between the Soviet Government and the Metropolitan-Vickers Electrical Co., Ltd., whereby the latter have undertaken to provide expert technical assistance in the manufacture of steam turbo-generating plant, industrial motors, switchgear, etc., in the works of the All Union Electro-Technical Combine, in Russia. Electric generating and distributing plant of the largest capacity will be manufactured, and will be used in connection with the five-year plan of industrial development.

Royal Visit to Engineering Works.

The interest of the Duke of York in industrial conditions and the welfare of the workers is well known, and on Wednesday last he paid a visit to the engineering works of G. A. Harvey and Co. (London), Ltd., as President of the Industrial Welfare Society. These works cover an area of about 25 acres, and employ nearly 2,000 workers. The Duke of York went through most of the "shops" and saw a wide range of production processes.

After visiting the tank-making department and galvanising department, His Royal Highness walked through the four 900-ft. bays of the new workshops. Two of these bays are devoted to the manufacture of steel furniture and office equipment, etc., and two to the making of industrial plant in steel plate up to 1½ in. in thickness, and in copper, aluminium, stainless steel, nickel, etc. Later, he visited the woodworking department, ambulance station, works canteen, and recreation hall, and, finally, the sports ground.

The ground, which, together with the pavilion, was presented by the firm to the Sports and Social Club, is about 14 acres in extent, is well laid out, and provides ample space for football, cricket, tennis and bowls. Both the founder of the firm, Mr. G. A. Harvey, and Mr. Sydney Harvey, the managing director, are firm believers in the beneficent effect of welfare activities. They are convinced that, not only is the physical fitness of the employee improved by such schemes, but that many valuable lessons in hygiene and first-aid are learnt, and, furthermore, the team spirit which is essential on the sports field engenders a spirit of loyalty and co-operation throughout the firm.

Trade with Russia.

Speaking before a large attendance of members of the Newcastle and Gateshead Incorporated Chamber of Commerce on April 30, Mr. Saul Bron, Chairman of the Russian Trade Delegation, emphasised the need for closer British trade relations with Russia. "Russia," he said, "was on the way to becoming one of the main industrial countries of the world. Her main requirements were machinery and other production equipment, and in the introduction of these she was utilising the services of many foreign experts. Of a total of about 20,000 of these foreign engineers and farmers, only some 250 were British. If better industrial relations could be established between the two countries, it might benefit many British industries considerably. Many people feared that there would be trouble at the end of the five-years' industrial plan. Their fears were groundless, and were largely the result of ignorance."

The Lord Mayor of Newcastle, Alderman David Adams, said that Mr. Bron had told him that Russia desired to purchase 20 to 30 timber carriers, 10 to 15 tankers, and 10 to 12 special passenger-carrying boats for their river trade. If the Government could be persuaded to accept these orders, as other Governments were prepared to do, Britain's idle shipyards might break into renewed activity, an activity which would have an effect on the country's industrial conditions as a whole.

That business connections between the two countries are increasing, though gradually, is shown by a brief review of recent Russian purchase figures. In the period 1928-29 the English manufactures in the total amount of Soviet purchases in this country were estimated at 41·9%, a figure which has now increased to 72·8%.

British Welding Interests in America.

An announcement of exceptional interest was made recently by the directors of Murex, Ltd. After the declaration of an interim dividend of 15%, an account was given of the recent activities of the company, in which it was announced that negotiations have been begun for the formation of a new subsidiary company in the United States, with a view to extending the welding interests in America. A new company has been formed, under the name of the American Murex Corporation, composed of Murex, Ltd., and the Metal and Thermit Corporation of America. This latter concern has an excellent welding organisation, and will handle the products of the American Murex Corporation. Following the amalgamation, in January last, of Alloy Welding Processes, Ltd., and the Premier Electric Welding Col, Ltd., under the name of Murex Welding Processes, Ltd., satisfactory results have been shown in their manufacturing operations, which have been concentrated in one factory.

Some Contracts.

The L.M.S. Railway Co. have placed an order with the General Electric Co., Ltd., Witton Works, Birmingham, for two 1,200 kw. remote-controlled mercury-arc rectifiers, for installation in the Upney Lane sub-station of the Barking-Upminster electrification scheme. These rectifiers will operate from an 11,000-volt 3-phase, 50-cycles supply. The G.E.C. have also been awarded a contract by the London Electric Railway Co. for the complete equipment of four sub-stations at Sudbury Hill, Alperton, North Ealing, and Northfields. This comprises a total of ten 1,500 kw. remote-controlled mercury-arc rectifiers, operating from an 1,000-volt, 3-phase supply, and feeding the traction system at 630 volts d.c., together with the whole of the automatic-control gear, air-blast transformers, high-speed circuit breakers, cabling, lighting, etc.

Steam-boiler plant to the value of £82,146 will be installed by Babcock and Wilcox, Ltd., in the Belfast Corporation's new harbour electricity station.

Sir William Arrol and Co., Ltd., Glasgow, have received from the Bombay, Baroda, and Central India Railway Co. an order for one 50-ton electric traverser, and another from Stewarts and Lloyds, Ltd., Coatbridge, Lanarkshire, for one 30-cwt. overhead crane and gantry.

A contract has been awarded to Charles Booth and Sons, of Lidget Green, Bradford, for the reconstruction of stations at Upminster, Hornchurch, Heathway, and Upney, in connection with the eltrification and widening of the Fenchurch Street and Southend section of the L.M.S.R.

Messrs. Midgley and Sutcliffe, of Bradford, have received an order from the Admiralty for "Richmond" new-design all-geared milling machines.

The British Thomson-Houston Co., Ltd., has received a contract for a three-months' supply of Mazda vacuum and gas-filled lamps from the Port of London Authority.

The B.B.C. has ordered from Crossley Bros., Ltd., Manchester, four 350-b.h.p. vertical oil engines, for the new Scottish Regional Station at Falkirk. The power plant for the Northern Regional Transmitting Stations at Moorside Edge has been supplied by Ruston and Hornsby, Ltd., Lincoln.

The placing of the following contracts is announced by the London and North-Eastern Railway Co.:—Reconstruction of Dean Road bridge, South Shields—John Lant, Ltd., Newcastle-on-Tyne; reconstruction of the fish market, Grimsby docks—A. Jackaman and Son, Slough, Bucks.; hot-water washing-out plant at Whitemoor Locomotive Depot—Economical Boiler Washing Committee, London; and two 10-ton steam travelling cranes, for Guide Bridge and Leeds district—Grafton and Co., Bedford.

The General Electric Co. have received from the London Electric Railway Co. further orders for 372 heavy railway motors.

The Sheffield Tramways and Motors Committee have placed the following contracts:—30 steel tramcar under-frames—Cravens Railway Carriage and Wagon Co., Sheffield; 6,000 air magnetic track shoes—the English Steel Corporation; 2,200 double slipper blocks—E. Lucas and Son.

Sheffield City Council have authorised the purchase of five additional Leyland double-deck omnibuses.

Holophane, Ltd., London have secured important contracts for street lighting in Valparaiso and Durban.

The British Thomson-Houston Co. have secured a contract for the supply, delivery, and installation of electricity distribution systems at Samanoud, Gharbieh Province, and Aboutig, Assiut Province, in Egypt, to the value of about £11,000.

British Insulated Cables, Ltd., Prescot, have received an order for the supply of overhead transmission to the value of £100,000, for use in linking-up the new Clarence Dock power scheme of Liverpool, forming part of the North West England and North Wales grid area.

In face of keen competition, Messrs. Hawthorn, Leslie and Co., Ltd., Hebburn, have secured a contract from the Portuguese Government, for the hull and machinery of two armed sloops. The news will be received with satisfaction at Hebburn, as Tyne shipbuilding is at its lowest ebb, and the firm has only one vessel on the stocks at present.

The Crown Agents for the Colonies have placed contracts to the value of £76,500 with Guest, Keen and Nettlefolds, Ltd., for the supply of 10,000 tons of 60-lb. steel rails, and 7,000 tons of steel sleepers, to be used for the re-alignment of 100 miles of track on the Nigerian railways.

The Great Western Railway Company has placed the following contracts:—Widening the main line between Filton Junction and Stapleton-road, Bristol, $2\frac{3}{4}$ miles, Messrs. Ernest C. Jordan and Son, Newport; automatic and manual telephone exchange at Cardiff, Queen Street station—Ericsson Telephone Ltd., Kingsway, London; reconstruction and widening of bridges between Newtown Yard and Cardiff General Station—John Morgan (Builders), Ltd., Cardiff; supply and erection of a steel viaduct to No. 6 hoist, West Side, East Dock, Cardiff Docks—A. D. Dawnay and Sons, Ltd., Cardiff; new engine shed and lifting shop and other works at Landore, Swansea—Messrs. F. Halcombe and Sons, Cardiff; two reinforced-concrete jetties, each to carry a new coal hoist at Port Talbot docks—Messrs. Christiani and Nielsen, London; overhaul of twin-screw steamer *St. Helier*—J. I. Thornycroft and Co., Ltd., London; supply and erection of two electrically driven air compressors for new concentration yard, Swindon—Belliss and Morcom, Ltd., Birmingham; overhaul of twin-screw steamer, *Great Southern*—Thomas Diamond and Co., Ltd., Cardiff; two 6-ton hand travelling cranes for Newport and Reading—Bedford Engineering Co., Bedford; supply and erection of manual and automatic telephone exchange, Wolverhampton—Ericsson Telephones, Ltd., London; supply and delivery of five Ford 30-cwt. tipping trucks at Theale, and 12 Fordson tractors for general use—Messrs. R. Pratt and Co., Sutton, Surrey; and five Cob tractors for experimental use at Paddington goods, Karrier Motors, Ltd., London.

The Westinghouse Brake and Saxby Signal Co., Ltd., have secured a contract for the supply of metal rectifiers to the borough of Bromley Electricity Department in connection with the change-over from d.c. to a.c. mains.

The Newcastle-on-Tyne Electric Supply Co. have placed a contract with Davidson and Co., Ltd., Belfast, for mechanical draft plant, fans and steel flues for the boilers, dust-collecting plant, and steel structural work for the new power station at Dunston. The contract is valued at over £100,000.

The "Sentinel" Wagon Works, Ltd., of Shrewsbury, have received from the Crown Agents for the Colonies an order for five "Sentinel-Cammell" standard type 100 h.p. double-articulated steam rail cars, for service on the Federated Malay States Railways. The value of the contract is about £35,000.

The Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, have received from Spain an order for 38 255-h.p. motors for motor-coaches and motor-freight vehicles, for use in the electrification of the Bilbao-Portugalette Railway's suburban line from Bilbao to Portugalette.

A total of 372 heavy railway motors of 240 b.h.p. each has been ordered by the Underground Electric Railways Co., London, from the General Electric Co., Ltd., Witton Works, Birmingham.

A sub-contract has been awarded to Harland and Wolff, Ltd., of Belfast, for caissons to be used in building the new bridge over the River Foyle at Londonderry, Ireland. The contract for the construction of this bridge was awarded to Dorman Long and Co., Ltd., Middlesbrough.

The Great Western Railway Co. have ordered from the Pulsometer Engineering Co., Ltd., Reading, eight electrically driven centrifugal pumps, for use in Barry Docks.

Electro-Depositing Metals and Alloys

Annual Conference of Electrochemical Society.

THE final session of the fifty-ninth annual convention of the Electrochemical Society, held at Birmingham, Ala., U.S.A., on April 23–25, was devoted to electroplating of metals and alloys. Among the many subjects discussed was the new art of platinum and palladium plating. A description of the process was given by Messrs. W. Keitel and H. E. Zschieguer, in which they stated that the chloride plating bath for platinum metals is not satisfactory, due to its short life; in consequence they developed a new bath, in which the platinum was present as the di-amminonitrite. Good, bright adherent deposits were obtained and the throwing power was good enough to allow all recesses to be covered. A similar bath was developed for palladium, and gave very satisfactory results.

Plating Noble Metals.

The plating of noble metals was discussed by Prof. S. Glasstone, who dealt with the limiting current at which a metal can be deposited. Apparently the literature of electrochemistry does not contain a simple equation permitting the calculation of the maximum, or limiting current density at which a metal can be deposited with 100% current efficiency. Prof. Glasstone developed such an equation on the assumption that the maximum rate of deposition is equal to the maximum rate at which the ions containing the metal to be deposited can diffuse up to the cathode. The values calculated in this manner were shown to be in good agreement with those observed, although discrepancies are likely to arise when there is a possibility of hydrogen evolution.

Depositing Chromium on Aluminium.

The deposition of chromium directly on aluminium was demonstrated by Messrs. H. K. Work and C. J. Slunder. Thin deposited layers of chromium, which have fairly good resistance to salt spray and atmospheric corrosion, were shown to be possible directly on aluminium. These deposits have a grey colour on leaving the plating bath, and must be buffed if higher lustre is required. Tests showed that these deposits protect aluminium from alkaline corrosion to a marked degree. Heavy deposits have been applied to certain aluminium alloys to resist abrasion.

High-Speed Nickel Plating.

The high-speed nickel-plating process in operation in England was described by Mr. E. R. Canning. He referred to a paper by Dobbs,* in which the practice of nickel plating carried out at several English concerns was outlined. This paper described the process whereby current densities of 24 amp. per sq. ft. were quite normal, and this involved the use of a warm nickel solution, which was agitated by means of compressed air, and continually filtered by the same process. Dobbs pointed out that with current densities of 20 amp. per sq. ft. (2·2 amp. per sq. dm.) and over, agitation of the electrolyte was necessary to avoid the possibility of forming pinholes. Owing to the considerable loss of throwing power, Mr. Canning advises against very high current densities. This loss may in some cases be so serious as to limit the use of current densities of about 24 amp. per sq. ft. (2·6 amp./sq. dm.) on certain articles, and it is this current density that he advises for nickel plating, working the solutions at temperatures of about 32° to 35° C., with constant agitation and filtration, at pH values of 5·6 to 5·8.

The cathode efficiency under these conditions is about 96 to 97%, and thicknesses of approximately 0·001 in. (0·025 mm.) are usually obtained in, roughly, 45 mins., with a variation over irregular-shaped articles of not more than 45%. In special cases these current densities are considerably exceeded, but in general the need for adequate protection of the base metal is the first consideration, and is rarely sacrificed for increased speed of deposition.

The thickness of nickel deposit mentioned may sound extravagant, but experience has shown that this is the minimum that can be safely applied to steel parts which are to be exposed to full atmospheric conditions prevailing in England. There the humidity of the atmosphere is considerably greater than prevails in the United States or upon the Continent of Europe, so that a much greater severity of test is imposed upon the plated articles. Where manufacturers are jealous of the reputation of the quality of their goods, thicknesses of nickel are advised of at least 0·001 in. (0·025 mm.) directly upon the steel base, or, in exceptional cases, as in the humid atmospheres of sub-tropical countries, composite deposits of nickel-copper-nickel, the intermediate copper layer being buffed before the reception of the final nickel coating.

* "The Commercial Deposition of Nickel" read before Electroplaters' and Depositors Technical Society, 1926.

Hot Nickel Solution.

The opinions of platers on the respective merits of the hot and cold nickel solutions are referred to in a report by Mr. O. P. Watts. The report deals with the volume and operating conditions of many of the hot nickel-plating solutions now in use in the United States and Canada. There was an incubation period of five years between the announcement of the advantages of heating the nickel-plating solution and its commercial adoption; since then the growth to 158,000 is reported to have occurred in ten years. Mr. Watts stated that the hot, concentrated nickel solution offers a means, not yet fully utilised, for producing a thick, ductile coat of metal in the same time that is now used in depositing an inadequate coating from the cold solution.

The Deposition of Chromium-Iron Alloy.

Experiments have been carried out by Messrs. G. Fuseya and K. Sasaki, with the object of finding out the best conditions for electro-depositing chromium-iron alloys containing more than 16% chromium. The results of the investigations form the basis of a paper presented at this convention. A chromic acid bath for chromium plating, with iron salts added, did not give any good deposit of the alloy, and sulphate baths containing from 52 to 130 g./L. Cr, 7 to 30 g./L. Fe, and 0·05 to 0·1 molar in H_2SO_4 were electrolysed between Cu cathodes and magnetite anodes. It was found that the longer the duration of electrolysis the lower the Cr content of the deposit. The higher the current density, and the lower the temperature of the acidity of the bath, the higher the Cr content of the deposit. The current efficiency of the plating bath is very small, and it is very difficult to cover uniformly the whole surface of an object, as the solution has very poor throwing power.

Depositing Tungsten from Aqueous Solutions.

A method developed for the electrodeposition of metallic tungsten from aqueous solutions was described by Messrs. C. G. Fink and F. L. Jones. The tungsten deposit is smooth, hard and coherent, having a high lustre. Like chromium, the electrodeposited tungsten needs no polishing if the plated article is previously polished. Tungsten has remarkable acid-resisting properties, which make it desirable as a protective coating for other metals. Several types of solutions have been investigated in regard to their usefulness as tungsten plating baths and alkaline solutions containing alkaline tungstates were considered to be the best. Control of the temperature, cathode current density and hydrogen ion concentration of the solution was stressed.

MARKET PRICES

ALUMINIUM.

99% Purity	£85 0 0

ANTIMONY.

English	£36 0 0
Chinese	23 15 0
Crude	22 0 0

BRASS.

Solid Drawn Tubes	lb.	9½d.
Brazed Tubes	lb.	11½d.
Rods Drawn	,,	9d.
Wire	,,	8d.
*Extruded Brass Bars	,,	4⅝d.

COPPER.

Standard Cash		£40 6 3
Electrolytic		43 0 0
Best Selected		42 0 0
Tough		41 10 0
Sheets		75 0 0
Wire Bars		45 5 0
Ingot Bars		45 5 0
Solid Drawn Tubes	lb.	10¾d.
Brazed Tubes	,,	10¾d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0 1 11½
‡Ferro Tungsten	,,	0 1 8½
§ Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
2-4% Carbon, scale 11/- per unit	ton	28 0 0
4-6% Carbon, scale 7/- per unit	,,	21 12 6
6-8% Carbon, scale 7/- per unit	,,	20 17 6
8-10% Carbon, scale 7/- per unit	,,	20 12 6
§ Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	,,	30 15 0
Guar. max. 1% Carbon, scale 13/6 per unit	,,	34 2 6
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	37 17 6
‡Manganese Metal 96-98% Mn.	lb.	0 1 3
‡Metallic Chromium	,,	0 2 7
§ Ferro-Vanadium 25-50%	,,	0 12 8
§ Spiegel, 18-20%	ton	6 17 6
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	5 17 6
20/30% basis 25%, scale 3/- per unit	,,	7 0 0
45/50% basis 45%, scale 5/- per unit	,,	10 0 0
70/80% basis 75%, scale 7/- per unit	,,	17 0 0
90/95% basis 90%, scale 10/- per unit	,,	25 6 0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	13 12 6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 6
Ferro Phosphorus, 20-25%	ton	15 10 0

FUELS.

Foundry Coke—	
S. Wales Export	£1 2 0 to £1 16 6
Sheffield Export	0 15 0 to 0 16 0
Durham Export	1 6 0 to 1 8 0
Furnace Coke—	
Sheffield Export	0 15 0 to 0 16 0
S. Wales ,,	0 16 6 to 0 17 6
Durham	0 13 6 to 0 14 0

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£56 0 0
*Commercial Ingots		46 10 0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0 0 10
*Cored Bars	,,	0 1 0

LEAD.

Soft Foreign	£11 17 6
English	13 5 0

MANUFACTURED IRON.

Scotland—	
Crown Bars	£10 5 0
N.E. Coast—	
Rivets	11 10 0
Best Bars	11 0 0
Common Bars	10 10 0
Lancashire—	
Crown Bars	10 5 0
Hoops	13 0 0
Midlands—	
Crown Bars.... £9 10 0 to	10 7 6
Marked Bars	12 0 0
Unmarked Bars	—
Nut and Bolt Bars........ £8 12 6 to	9 0 0
Gas Strip	10 17 6
S. Yorks.—	
Best Bars	11 0 0
Hoops	12 0 0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	10d.
*Cored Bars	,,	1/-
†Strip	,,	1/0¼
†Sheet to 10 W.G.	,,	1/0¾
†Wire	,,	1/0⅝
†Rods	,,	1/0¼
†Tubes	,,	1/5
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£3 12 0
Foundry No. 1	3 16 0
,, No. 3	3 13 6
N.E. Coast—	
Hematite No. 1	3 6 0
Foundry No. 1	3 1 0
,, No. 3	2 18 6
,, No. 4	2 17 6
Cleveland—	
Foundry No. 3	2 18 6
,, No. 4	2 17 6
Silicon Iron	3 1 0
Forge No. 4	2 17 0
N.W. Coast—	
Hematite	4 6 6
Midlands—	
N. Staffs Forge No. 4	3 6 0
,, Foundry No. 3	3 11 0
Northants—	
Forge No. 4	3 2 6
Foundry No. 3	3 7 6
Derbyshire Forge	3 6 0
,, Foundry No. 3	3 11 0
West Coast Hematite	4 4 6
East ,, ,,	4 1 6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6 0 0 to £7 10 0
Bars, hammered, basis	£17 10 0 ,, £18 10 0
Blooms	£10 0 0 ,, £12 0 0
Keg steel	£32 0 0 ,, £33 0 0
Faggot steel	£20 0 0 ,, £24 0 0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£31 0 0
,, Braziery	31 0 0
,, Wire	—
Brass	22 0 0
Gun Metal	30 0 0
Zinc	4 15 0
Aluminium Cuttings	46 0 0
Lead	9 5 0
Heavy Steel—	
S. Wales ......£2 6 0 to	2 7 0
Scotland	2 2 6
Cleveland	2 2 6
Cast Iron—	
Lancashire	2 5 0
S. Wales	2 8 0
Cleveland ....£2 7 0 to	2 8 6
Steel Turnings—	
Cleveland	1 8 6
Lancashire	1 0 0
Cast Iron Borings—	
Cleveland	1 3 6
Scotland	1 13 0

SPELTER.

G.O.B. Official	—
Hard	£8 7 6
English	10 17 6
India	9 12 6
Re-melted	9 12 6

STEEL.

Ship, Bridge, and Tank Plates—	
Scotland	£8 15 0
North-East Coast	8 15 0
Midlands	8 17 6
Boiler Plates (Land), Scotland..	10 10 0
,, ,, (Marine) ,,	10 10 0
,, ,, (Land), N.E. Coast	10 0 0
,, ,, (Marine) ,,	10 10 0
Angles, Scotland	8 7 6
,, North-East Coast	8 7 6
,, Midlands	8 7 6
Joists	8 15 0
Heavy Rails	8 10 0
Fishplates	12 0 0
Light Rails	8 15 0
Sheffield—	
Siemens Acid Billets	9 10 0
Hard Basic .... £8 12 6 to	9 2 6
Medium Basic .. £7 2 6 to	7 12 6
Soft Basic	6 5 0
Hoops ....£9 10 0 to	9 15 0
Manchester—	
Hoops	9 15 0
Scotland, Sheets 20 W.G.	9 10 0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten.	lb.	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to 3/16 in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£105 10 0
English	106 10 0
Australian	106 10 0
Eastern	107 0 0
Tin Plates I.C. 20 × 14 ..... box	15/-
Block Tin Cash	£119 5 0

ZINC.

English Sheets	£20 0 0
Rods	22 12 6
Battery Plates	15 0 0

* McKechnie Brothers, Ltd., quoted May 8. † C. Clifford & Son, Ltd., quoted May 8. ‡Murex Limited, quoted May 9.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices, f.o.b. Liverpool or Stations in Lancashire :—Wrought Iron Bars, £10 5s. 0d. ; Mild Steel Bars, £6 15s. 0d. ; Wrought Iron Hoops, £12 ; Best Special Steel Baling Hoops, £8 10s. 0d. to £8 15s. 0d. ; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 0s. 0d. to £8 5s. 0d ; C. R. & C. A. Steel Hoops, £11 10s. 0d. to £12 0s. 0d ; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted May 8 § Prices quoted May 9, ex warehouse.